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by Franklin B. Lewis, Michael L. McManus
and Noel F. Schneeberger

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Guidelines for the Use of GYPCHEK to Control the Gypsy Moth

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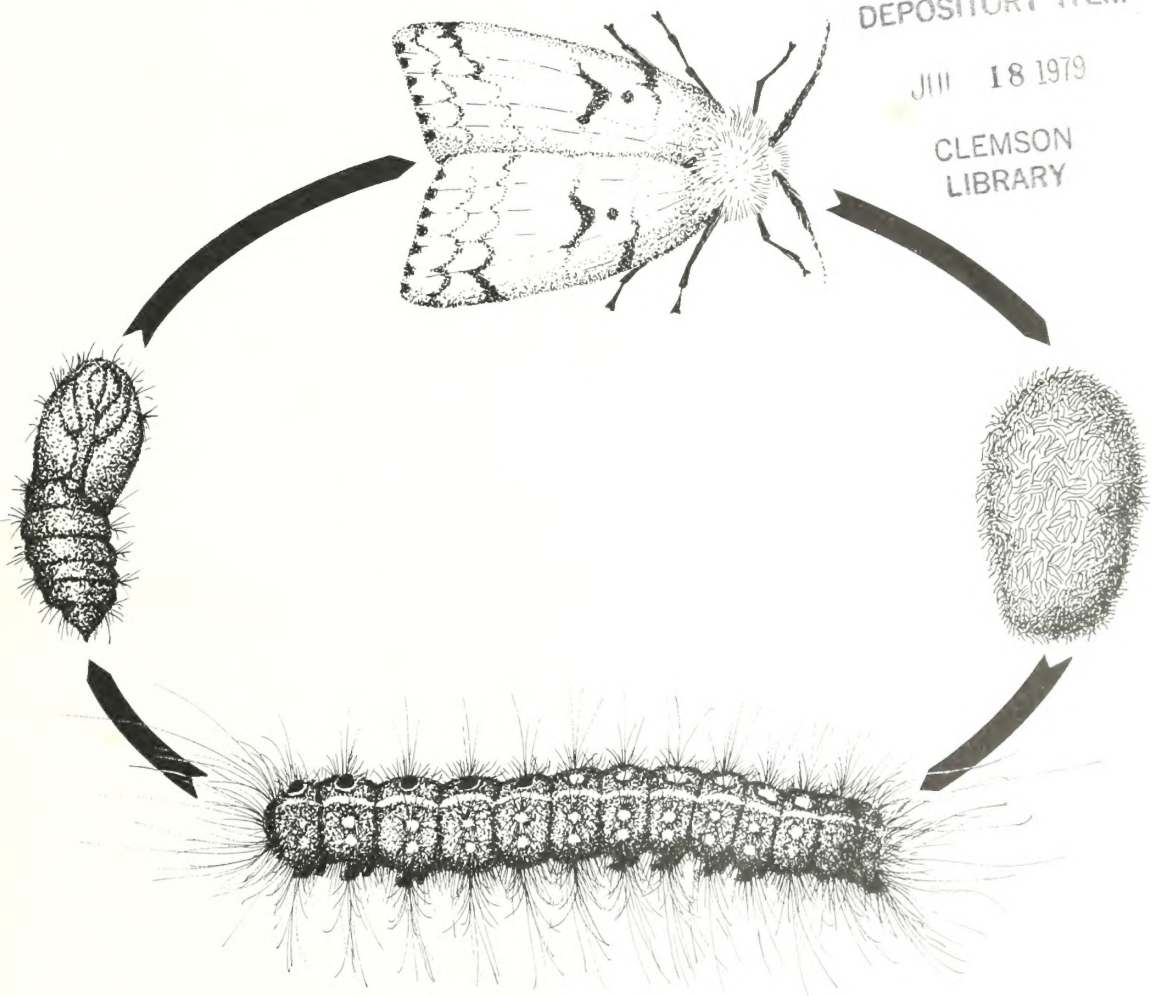

FOREST SERVICE RESEARCH PAPER NE-441
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370 REED ROAD, BROOMALL, PA. 19008

The Authors

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MANUSCRIPT RECEIVED FOR PUBLICATION 16 FEBRUARY 1979

Abstract

This paper presents positive and negative attributes of GYPCHEK for evaluation by land managers contemplating gypsy moth control. Special precautions and procedures are outlined. Environmental and ecological considerations are discussed and results to be expected from the use of GYPCHEK in gypsy moth control are presented.

Caution about Pesticides

This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

SB 310

INTRODUCTION

A LAND MANAGER frequently must answer two important questions when confronted with a gypsy moth infestation: Should I institute control action? What control approach should I employ? And there are other important questions that must be asked, weighed, and answered: What is the cost? What are my short and long range objectives? What are the economic, political, environmental, and ecological constraints? Are there operational difficulties and problems? What is my time frame?

These guidelines were developed to aid the land manager in the selection and use of GYPCHEK,[1] a biological insecticide for gypsy moth control.

WHAT IS GYPCHEK?

GYPCHEK is an insecticide prepared from gypsy moth larvae that have been killed by the nucleopolyhedrosis virus (NPV). The active ingredient in GYPCHEK is the virus, which is embedded in a protein particle called the polyhedron. The powder, milled to pass through 50-mesh screens, contains the virus, insect material, and a small amount of harmless bacteria. The insecticidal activity of GYPCHEK, determined by a bioassay procedure, is printed on the label as so many activity or potency units per gram (See Appendix). These activity or potency units are used to prescribe the field dosage. The present field dosage is 25 million potency units per acre (0.4 ha), usually applied twice.

GYPCHEK is specific against the gypsy moth and has no effect on other insects. GYPCHEK has shown no adverse effects on fish or game birds, vertebrates, or man. If the powder gets into the eyes, it can cause moderate irritation because GYPCHEK contains some gypsy moth hairs.

GYPCHEK is a proteinaceous material and as such is subject to degradation by sunlight and heat.

HOW DOES IT KILL GYPSY MOTH LARVAE?

After the gypsy moth larvae ingest viral polyhedra along with the foliage, the virus rods are liberated from the polyhedra and attack internal tissues and organs of the larvae. The rods multiply rapidly, eventually causing disintegration of the internal tissues and death. The entire process takes 10 to 14 days, depending on the temperature. Larvae about to die have a characteristic oily, greasy appearance (Fig. 1). Before this time, virus-infected larvae are not visibly different from normal larvae (Fig. 2). Virus-killed larvae typically have an inverted-V appearance and are extremely fragile to the touch (Fig. 3).

HOW DO YOU USE GYPCHEK?

GYPCHEK is registered for aerial application only. The procedures for mixing GYPCHEK are found on the product labeling (Appendix). The following are special reminders on the use of GYPCHEK.

[1]The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1.—Virus-infected gypsy moth larvae about to die have a characteristic oily, greasy appearance.

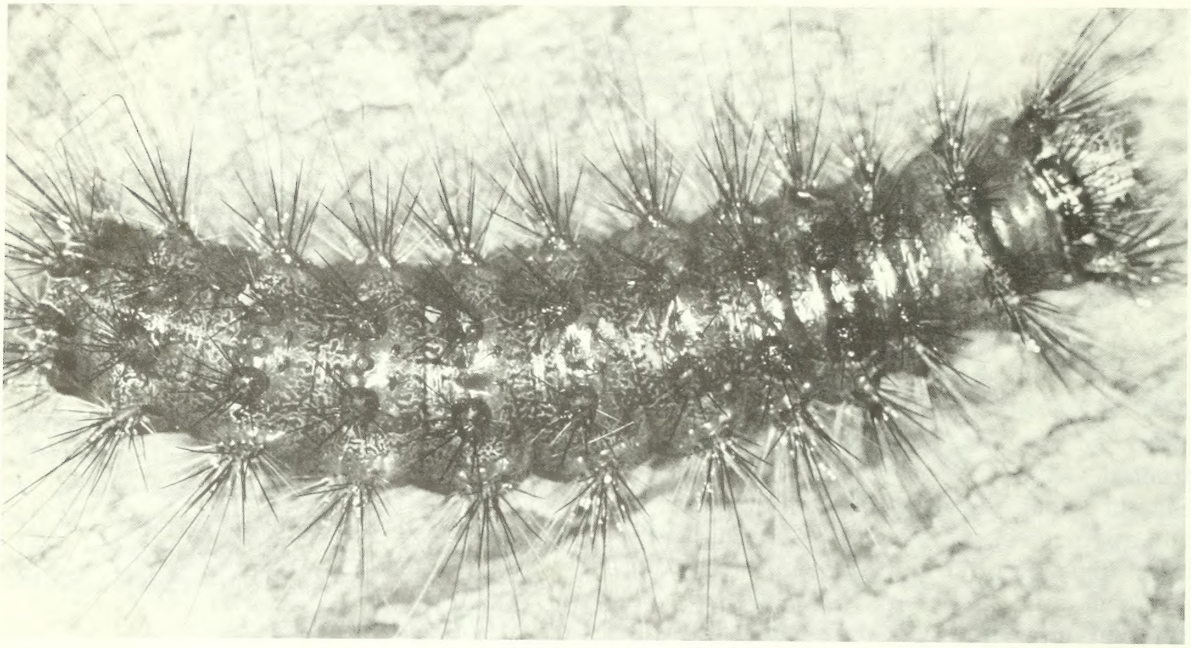

Figure 2.—Normal gypsy moth larva.

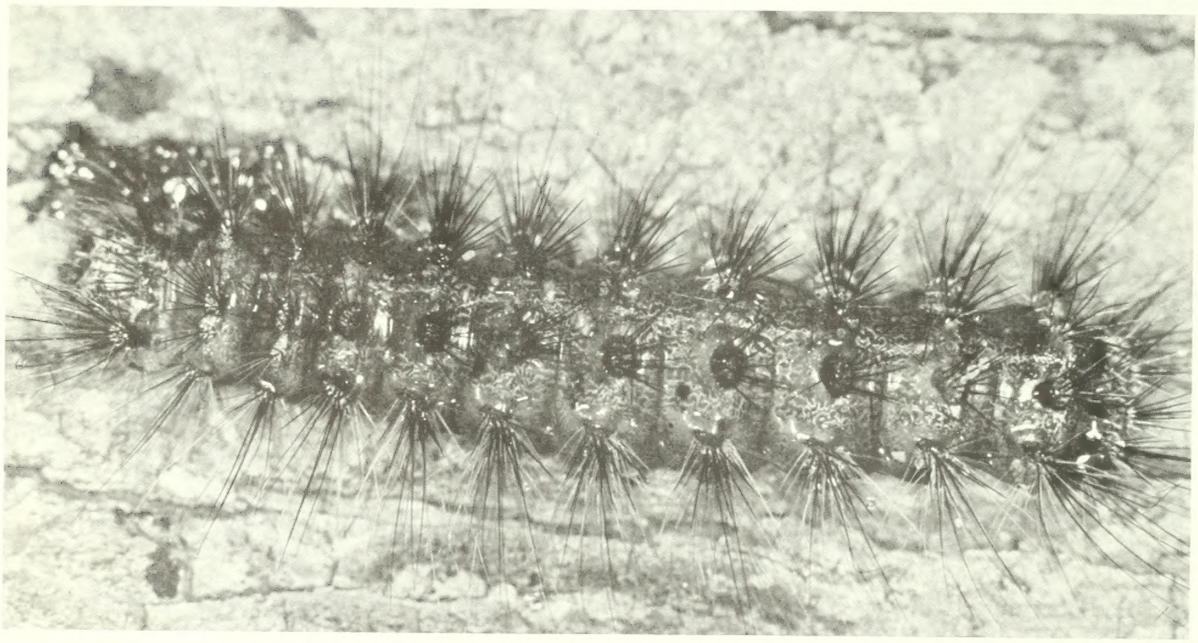

Figure 3.—Virus-killed gypsy moth larva.

Timing

The active ingredient in GYPCHEK is much more effective against small larvae than against large. Two primary factors should be considered: (1) larval size—application should be made when the majority of larvae are 1st and 2nd instar, (2) leaf size—since GYPCHEK is a stomach insecticide, leaf expansion should be at the maximum consistent with larval size. Expansion of small leaves will produce untreated leaf surfaces and can dilute the effect of the treatment. Thus, the timing of the first application should balance larval size and leaf expansion—with greater emphasis on larval size.

A second application of the material is recommended because: (1) the expected life of GYPCHEK in the field is about 3 days with present formulations; there will be slight activity for 4 to 6 days; (2) further expansion of leaves requires coverage of the newly exposed surfaces; (3) further hatch and dispersal of gypsy moth larvae can add a significant number of insects not ingesting viable GYPCHEK from the first application, (4) additional coverage of leaves with active GYPCHEK extends the period of exposure of larvae that may have received a sublethal dose or none at all.

The second application should be timed about 5 to 10 days after the first, but should not be applied if the larvae are at the more resistant instars (4th or larger).

Size of treatment area

Although there is no limit to the size of the area that can be treated, there are two important considerations. Coverage should be thorough—both vertically and horizontally. In heavy populations (4,000 or more egg masses per acre) the likelihood of reinvasion of treated blocks increases dramatically. Small blocks less than 50 acres should not be treated as they are apt to be overrun by invading larvae searching for food. The invading larvae will not be controlled because the GYPCHEK will have been degraded.

Therefore, if reinvasion is a threat, small treatment areas should be avoided or the treatment blocks should be enlarged. Reinvasion does not pose a problem in isolated infestations that can be treated in their entirety.

Population density and quality

There has been much theorizing about the gypsy moth population levels at which GYPCHEK would have the greatest effect. European literature indicates that the gypsy moth NPV is considered most effective at low, building population levels than at the peak of the insect outbreak. Most testing has been in the range of 300 to 3,000 egg masses per acre. We do not know how effective GYPCHEK would be against very low populations (less than 100 egg masses per acre) or very high populations (more than 4,000 egg masses per acre). Table 1 summarizes the results of field tests with GYPCHEK since 1974.

Using numbers of egg masses per acre to estimate population density can be mislead-

Table 1.—Effects of aerially applied GYPCHEK on egg mass populations of the gypsy moth[a]

Year	Population density		Foliage protection[b]
	Pretreatment	Posttreatment	
	Egg masses/acre		
1974[c]			
Treatment	1,817	2,124	Not acceptable
Control	1,732	5,550	Not acceptable
1975[c]			
Treatment	960	600	Acceptable
Control	1,000	1,240	Not acceptable
1976[c]			
Treatment	2,009	475	Acceptable
Control	2,606	1,369	Not acceptable
1977[d]			
Treatment	1,260	356	Acceptable
Control	1,455	2,293	Not acceptable
1978[d]			
Treatment	528	4	Acceptable
Control	478	5	Acceptable

[a]Averages of all plots. Data presented for general comparisons. The number of egg masses per acre ranged from 250 to 3,200.
[b]Acceptable if total defoliation was less than 50 percent.
[c]Highly purified gypsy moth NPV.
[d]Present GYPCHEK product.

ing since a small number of large egg masses (600 or more eggs per mass) can produce more larvae than a much higher number of small egg masses (less than 200 eggs per mass). Also, larvae hatching from small numbers of large egg masses are thought to be more vigorous and healthy then larvae hatching from large numbers of very small egg masses.

In 1978, where treated populations averaged about 500 egg masses per acre, there was a total collapse of treated and untreated populations. This collapse was neither predicted nor expected.

The efficacy of GYPCHEK can be markedly affected by the quality or behavior of the larval populations being treated. Points to consider regarding the quality of the larval population and its relationship with GYPCHEK are:

- The natural virus load and a way to predict it.
- Gypsy moth populations may experience a total collapse at about 500 egg masses per acre—far below densities where such occurrences are expected.
- Information is lacking about how best to assess the quality of the larval population and when and how to apply treatment.

Mixing

Since GYPCHEK is an insoluble powder and will be applied as a suspension, it should be thoroughly premixed by vigorous mechanical agitation in a small amount of water before it is added to the spray mixing tank. Good agitation must be maintained in the mixing tank and in the aircraft. At least 15 minutes should elapse between final mixing of GYPCHEK and loading into the aircraft.

It is relatively simple to mix GYPCHEK. The following is the recommended sequence for mixing:

1. Pump and meter water into the mixing tank to about one-half to two-thirds of the total volume of water for the particular mix.

Lewis, Franklin B., Michael L. McManus, and Noel F. Schneeberger.
1979. **Guidelines for the use of GYPCHEK to control the gypsy moth.** Northeast. For. Exp. Stn., Broomall, PA
9 p., illus. (USDA For. Serv. Res. Pap. NE-441)

This paper presents positive and negative attributes of GYPCHEK for evaluation by land managers contemplating gypsy moth control. Special precautions and procedures are outlined; environmental and ecological considerations are discussed; and results to be expected from the use of GYPCHEK in gypsy moth control are presented.

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Keywords: Nucleopolyhedrosis virus, NPV microbial control, pest management

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2. Carefully dissolve the proper amount of the ultraviolet screen, Shade,® in this water. Eliminate all lumps—agitate thoroughly.
3. Add the necessary amounts of molasses and sticker while vigorously agitating the mix. Add the remaining water to complete the required mix.
4. Continue agitating for 5 to 10 minutes. At this point the formulation can be held for 1 or 2 days if necessary.
5. To complete the formulation when spraying is scheduled, add the premixed GYPCHEK suspension to the tank and thoroughly mix for 10 to 15 minutes before loading into the aircraft.

If this procedure is followed, only 10 to 15 minutes will be needed to prepare final formulation once the decision to spray has been made. An efficient mixing crew can easily have the next tank mix ready by the time the aircraft returns to the loading area.

Special precautions in mixing and applying GYPCHEK

There are a few points to keep in mind when mixing and applying GYPCHEK:

- Follow the label directions carefully. The pH of water used in the mixing must be between 5.5 and 7.5. Stagnant pool water should not be used if a suitable source of flowing water is available.
- The active ingredient in GYPCHEK is a living organism and will be injured or killed by heat. GYPCHEK should be premixed only in short sequences to prevent temperature buildup. This is best accomplished by using an electric blender. Be sure to thoroughly rinse the premixed GYPCHEK while adding it to the mixing tank. Aerial spraying systems that generate high temperatures should be avoided. The spray mix should never be allowed to reach 100°F or held at temperatures above 90°F for long periods.
- All efforts should be made to minimize the time from final mixing to application. Retention of the final formulation in the mixing tank should not exceed 48 hours.
- Apply the material in the evening since this will allow GYPCHEK to be fed on for several hours before the degrading effects of sunlight begin. This timing also will coincide with the normal feeding period of the insect.
- Keep premixed batches of GYPCHEK calibrated for spray blocks cool (on ice) until they are placed in the mixing tank. These batches can be made up well in advance (1 to 2 weeks) of planned spray dates. The size of the premixed batches will be decided by the planned operation and can be adjusted to the size of the available mixing equipment. Premixes can be prepared as easily for large operations as for small ones. They should be refrigerated until use. Plastic ice chests will keep the premixes sufficiently cool at the mixing and loading site.
- Since the premixed GYPCHEK is added to the mixing tank last, all other ingredients can be mixed and held for several days if necessary. GYPCHEK can be added to the mixing tank when spray conditions are acceptable. Do not use the spray tank agitation system in the aircraft as a substitute for the mixing tank on the ground.
- Rinse Beecomist® nozzles after 2 to 3 loads have been delivered. If flat fan nozzles are used, remove and clean the nozzle screens after each load or do not use nozzle screens.

HOW TO MEASURE EFFECTS OF GYPCHEK

Several methods can be used to measure the efficacy of GYPCHEK. These can be placed into two general categories: (1) population change, and (2) defoliation reduction.

Population changes are monitored in the following ways:

- Changes in egg-mass density based on the number of egg masses per acre before treatment compared to egg masses per acre after treatment as measured in fixed sampling points. It is important to determine the number of viable eggs in the egg masses. The number of residual egg masses is one primary indicator of efficacy.
- Burlap bands placed on trees in treated and untreated areas provide resting areas for larger larvae. This technique provides good information on the relative abundance of

larvae in treated and untreated areas, and an insight into any catastrophic mortality in the populations.

- Timed walk counts. Slow walks of 5 or 10 minutes through treatment and check areas will provide a good estimate of the relative densities of larval populations. Living and dead larvae are recorded as seen during this slow walk. This technique and the burlap technique should be used only when the larvae are large and exhibit their diurnal behavior pattern.

Damage estimates, the second primary efficacy measurement, are based on visual defoliation measurement at the same prism points where the egg mass counts were made. Estimates should be made on oaks and other tree species. Defoliation estimates can be either total or net. Total defoliation refers to the gross amount of defoliation at the measurement point uncorrected for initial defoliation before spraying. Net defoliation is the gross amount minus the prespray defoliation; this method better accounts for the protection afforded by the treatment. Net defoliation should always be used if there is a significant amount of defoliation before spraying. This requires a defoliation estimate just before treatment as well as the final defoliation estimate.

WHAT CAN BE EXPECTED FROM THE USE OF GYPCHEK

At the outset it should be noted that the complete elimination of the population cannot be expected from the use of GYPCHEK. The positive and negative aspects of GYPCHEK are shown in Table 2.

Reduction of population

Proper application of GYPCHEK can reduce the number of residual egg masses in treated areas by 75 percent, though greater reduction can often be achieved. Under certain circumstances (1976 spray test), egg viability in the succeeding generation also may be markedly reduced.

Protection of foliage

When defoliation of most trees exceed 50 percent, refoliation will occur; in the process of refoliation, stored foods in the tree are used and the vigor of the tree is subsequently reduced, rendering it susceptible to opportunistic mortality-causing organisms. Preventing refoliation can be an important management objective.

Foliage protection sufficient to prevent refoliation is possible when GYPCHEK is ap-

Table 2.—Positive and Negative Attributes of GYPCHEK

Positive	Negative
No effect on beneficial forms of life	Relatively slow acting
Natural component of gypsy moth ecosystem	Considerable care must be used in timing and application
Selective against gypsy moth	Affects only gypsy moth, this is negative only when another pest in the same area is at damaging levels
Affords population reduction (75 percent minimum)	
Affords foliage protection (prevents refoliation)	Short residual activity
Insect does not develop resistance	At present more expensive then conventional insecticides
Suited to a pest management system	Quantities are limited
Ecologically and environmentally acceptable	At present must be applied twice

plied properly and at the right time, even though 10 to 15 days are needed for the material to exert its effect.

Less than 55 to 60 percent total defoliation can be expected, and, in many cases, less than 30 percent.

ENVIRONMENTAL CONSIDERATION

GYPCHEK has no effect on the natural enemies of the gypsy moth, and no degrading effect on the environment in which it is applied. This can be advantageous where ecological and environmental considerations are of paramount importance in the selection of an insecticide. Extensive tests have shown that GYPCHEK does not affect birds, fish, or other wildlife, and that it has a shorter residual effect on bark and in soil than the natural-occurring virus.

ROLE OF GYPCHEK IN GYPSY MOTH PEST MANAGEMENT

Conclusive data on the long-range effect of GYPCHEK on gypsy moth populations is not yet available. GYPCHEK has yet to be tested in combination with other control tools to determine the combined effects, either short or long term.

Table 3 shows the objectives and constraints of land managers when planning treatments. GYPCHEK fits into pest management plans where:

1. Environmental considerations are critically important.
2. The cost of treatment is not a major consideration.
3. Protection of foliage and reduction of larvae and egg masses is desired, but total larval elimination is not required.
4. The area will be used immediately after treatment.
5. The effect of treatment is not expected to exceed 3 years.
6. The natural mortality-causing complex of the gypsy moth must be protected.

Table 3.—Variables usually considered by land managers when contemplating gypsy moth control

User	Objective	Type of injury from gypsy moth	User constraint			Area usually considered
			Willingness to fund treatment cost	Environmental considerations	Expected duration of effects of treatment	
Timber grower	Wood production	Growth loss, tree stress, mortality	Nil to low	Minimum	Long	Large
Watershed manager	Water quality and quantity	Growth loss, tree stress	Moderate	High	Short to moderate	Medium
Recreation manager	Good public relations, prevent immediate loss of revenue	Defoliation, frass, larvae, tree mortality	Moderate to high	Moderate to high	Short to moderate	Small to medium
Public individuals and municipalities	Reduce maintainence and hazards, prevent nuisance and tree mortality, and removal and replacement costs	Defoliation, frass, larvae, tree loss	High	Moderate to high	Short	Small to medium

APPENDIX

TECHNICAL BULLETIN
GYPCHEK BIOLOGICAL INSECTICIDE

Gypchek Biological Insecticide consists of polyhedra of the gypsy moth nucleopolyhedrosis virus. Care must be taken in the mixing and application of this product. Stickers and u.v. protectants may enhance performance of this product. Apply in sufficient spray mixture for thorough and uniform coverage. This spray mixture is for aerial application only. Application is at the rate of 2 gal. (U.S.) finished spray per acre. Use boom and nozzle systems designed to result in droplets 150-400 mmd. (For example:Beecomist 275 or flat-fan 8006).

Tank Mixture (per gallon)

Gypchek	Amount to result in 25.0 to 125.0 million gypsy moth potency units per acre.
Molasses	0.25 gallon
Chevron Sticker	3 fl. oz.
Shade^{R}	1.0 lb. (same amount for 2 gallon)
Water	0.72 gallon

IMPORANT:Check pH of water from field source. If pH exceeds 7.5 or is below 5.5, add sufficient acid or base to adjust pH to approximately 7. NEVER USE CHLORINATED WATER IN THE SPRAY FORMULATION.

Mixing sequence for conventional mixing equipment.

1. Fill tank with water and start agitation.
2. Add acid or base if necessary to adjust pH.
3. Add sunscreen (Shade^{R}) by slowly pouring onto the surface of mixture under agitation. Avoid large lumps of powder.
4. Add molasses by slowly pouring into water and mix thoroughly.
5. Add sticker.
6. Add GYPCHEK. Mixing time can be reduced by premixing Gypchek with a small amount of water in a blender before adding to tank mix. Final formulation should be mixed for 10-30 minutes.

Note: Read label thoroughly before using. Follow all label cautions and directions.

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS

WARNING
Causes eye irritation. Do not get in eyes.

FIRST AID

In case of eye contact,immediately flush eyes with plenty of water for at least 15 minutes.For eyes,call a physician.

ENVIRONMENTAL HAZARDS

Avoid application to lakes,streams,or ponds. Do not contaminate water by cleaning of equipment or disposal of wastes.

DIRECTIONS FOR USE
GENERAL CLASSIFICATION

It is a violation of Federal law to use this product in a manner inconsistent with its labeling.

For foliar protection from gypsy moth larvae make 2 applications 7 to 10 days apart at the rate of 25.0 to 125.0 million gypsy moth potency units per acre in sufficient water for thorough and uniform coverage. Stickers and u.v. protectants may enhance performance of this product. Refer to technical bulletin for mixing and application instructions.

NEVER USE CHLORINATED WATER IN THE SPRAY FORMULATION.

STORAGE AND DISPOSAL

Activity may be impaired by storage above 90°F.

Do not contaminate water,food or feed by storage or disposal. Open dumping is prohibited. Do not reuse empty container.

Pesticide, spray mixture, or rinsate that cannot be used should be disposed of in a landfill approved for pesticides or buried in a safe place away from water.

Container disposal: Triple rinse and dispose of in an approved landfill or bury in a safe place.

Consult Federal,State, or local disposal authorities for approved alternative procedures.

GYPCHEK

BIOLOGICAL INSECTICIDE
FOR THE
GYPSY MOTH

Active Ingredient*:
(Polyhedral inclusion bodies of gypsy moth nucleopolyhedrosis virus). 20%

Inert Ingredients. 80%

Total 100%

*This lot contains at least ___ million gypsy moth potency units per gram.

KEEP OUT OF REACH OF CHILDREN

WARNING

See back of tag for additional precautionary statements.

For use by or under the supervision of U.S. Forest Service.

Notice: The U.S. Forest Service makes no warranty, expressed or implied including the warranties or merchantability and/or fitness for any particular purpose, concerning this material except those which are contained on the U.S. Forest Service's label.

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EPA REGISTRATION NO. 27586-2

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Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
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by Keith F. Jensen and Leon S. Dochinger

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GROWTH RESPONSES OF WOODY SPECIES TO LONG- AND SHORT-TERM FUMIGATION WITH SULFUR DIOXIDE

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Abstract

Height growth of silver maple, white ash, yellow-poplar, sycamore, eastern cottonwood, and white spruce seedlings was not significantly influenced by 0.15 ppm SO_2 for 8 hours/day, 5 days/week. A fumigation treatment of 0.25 ppm SO_2 for 8 hours/day, 5 days/week did not significantly affect height growth of black alder, yellow-poplar and white spruce seedlings but significantly reduced the height growth of eastern cottonwood, green ash, and sycamore seedlings. Exposure to toxic concentrations of SO_2 (1 to 4 ppm) for 2 to 8 hours significantly affected the height growth and caused leaf injury in silver maple and yellow-poplar seedlings. Growth was only suppressed for 14 days after the toxic fumigation because by that time new leaves had formed and normal growth had resumed.

DESPITE the increase in air pollution research in recent years, the impact of air pollutants on growth and productivity of forest and agricultural crops is still largely unknown. Information is available for some agricultural crops: soybean (Heagle et al. 1974), sweet corn (Heagle et al. 1972), radish (Tingey et al. 1971a), tomato (Oshima et al. 1975), and tobacco (Tingey and Reinert 1975), but little or no data are available for most tree species.

To fill this information void, we are conducting studies to determine what effects ambient or near-ambient levels of pollutants have on growth of tree seedlings. To date these studies have shown that the growth of sycamore, sugar maple, and silver maple seedlings were significantly reduced by either 0.25 ppm or 0.30 ppm ozone (Jensen 1973, Jensen and Masters 1975). Growth of hybrid poplar clones was slowed by both 0.15 ppm ozone and 0.25 ppm sulfur dioxide (Jensen and Dochinger 1974, Dochinger and Jensen 1975).

The objectives of this study are: 1) to evaluate the influence of low or near-ambient levels of sulfur dioxide on growth of tree seedlings and 2) to compare the responses of tree species to low levels of SO_2 with the responses of seedlings exposed to toxic levels of the same pollutant.

MATERIALS AND METHODS

In the first experiment, twenty-four 1-year-old seedlings each of black alder (*Alnus glutinosa* (L.) Gaertn.), green ash (*Fraxinus pennsylvanica* Marsh.), yellow-poplar (*Liriodendron tulipifera* L.), sycamore (*Platanus occidentalis* L.), and eastern cottonwood (*Populus deltoides* Bartr.) and 2-year-old seedlings of white spruce (*Picea glauca* (Moench) Voss) were potted in a 1:1 sand-soil potting mixture in 15-cm plastic pots. The seedlings of each species were randomly assigned to either a control group or fumigation treatment with 0.25 ppm SO_2 for 8 hours/day, 5 days/week. Treatments were applied to the seedlings in two 8x8x8-foot polyethylene-covered chambers inside a greenhouse. (Heagle et al. 1972).

Height was measured when the seedlings were placed in the chambers in mid-June and remeasured every two weeks for 14 weeks. Leaf counts were made on September 9 and leaf width and length measurements were made on September 3. All data were statistically analyzed by species using a completely randomized design.

In the second experiment twenty-four 1-year-old seedlings each of silver maple (*Acer saccharium* L.), white ash (*Fraxinus americana* L.), yellow-poplar, sycamore, and eastern cottonwood and 2-year-old seedlings of white spruce were potted in late May as in the first experiment. Seedlings of each species were randomly assigned to either fumigation with 0.15 ppm SO_2 for 8 hours/day, 5 days/week, or the control group. The treatments were applied in the same chambers used in the first experiment.

Height was measured as in the first experiment. Leaves were counted and their area measured with an electronic area meter on July 18. All data were statistically analyzed by species, using a completely randomized design.

In the third experiment, 1-year-old seedlings of silver maple, yellow-poplar, and eastern cottonwood were potted as above and placed on a greenhouse bench in mid-July. After the seedlings had produced an average of 15 leaves, 80 seedlings of each species were selected and 8 randomly assigned to each of the following treatments: 1) 1 ppm SO_2 for 2 hours, 2) 1 ppm SO_2 for 5 hours, 3) 1 ppm SO_2 for 8 hours, 4) 2.5 ppm SO_2 for 2 hours, 5) 2.5 SO_2 for 5 hours, 6) 2.5 ppm for 8 hours, 7) 4 ppm SO_2 for 2 hours, 8) 4 ppm SO_2 for 5 hours, 9) 4 ppm SO_2 for 8 hours, and 10) control.

The fumigation treatments were applied to the seedlings in a 2×3×4-foot polyethylene covered chamber located inside an environmental control unit. The chamber had a closed circulation system. The light intensity at plant height inside the chamber was 2000 foot-candles. The temperature was 26±2°C and relative humidity 60±15 percent. The seedlings were returned to the greenhouse immediately after fumigation.

Seedling height was measured 1 week before fumigation, on the day of fumigation, and 2 and 4 weeks after fumigation. Leaf injury was assayed 2 days after fumigation by separating the leaves into three classes, 1) no injury, 2) less than 50 percent injured, and 3) more than 50 percent injured. Height, determined 4 weeks after fumigation, and leaf injury were statistically analyzed by species in a completely randomized design.

The SO_2 concentrations in the treatment chambers in all three experiments were continually monitored with a Beckman 906A[1] SO_2 analyzer. Sulfur dioxide was added to the chambers from either tanks of SO_2 or SO_2 and nitrogen combined.

RESULTS

No significant change in height growth was found for any species fumigated with 0.15 ppm SO_2. However, the final heights of eastern cottonwood, green ash, and sycamore seedlings fumigated with 0.25 ppm were significantly less than the heights of the corresponding unfumigated seedlings (Fig. 1). No air pollution injury was observed on the leaves of any of the seedlings in the fumigation treatment.

No significant differences were found in either number of leaves or leaf area between the seedlings in the control treatment and the seedlings fumigated with 0.15 ppm SO_2. With the 0.25 ppm treatment no significant change was found in either leaf length or width, but the number of leaves on eastern cottonwood and black alder seedlings was significantly less in the fumigated treatment than in the control treatment (Table 1). Conversely, yellow-poplar seedlings in the fumigated treatment had more leaves than seedlings in the control treatment.

Table 1. The effect of 0.25 ppm SO_2 on leaf number.

Species	Number of leaves per seedling	
	Control	Fumigated
Green ash	18	15
Cottonwood	29	16**
Sycamore	16	12
Yellow-poplar	20	27*
Black alder	29	18*

*Significant at the 5 percent level.
**Significant at the 1 percent level.

Fumigating with toxic levels of SO_2 significantly affected the height of silver maple and yellow poplar (Fig. 2). Significant differences were found both among fumigations and lengths of exposure. Growth reductions were the greatest after 8 hours of treatment for both species and with 4 ppm SO_2 for yellow-poplar and 1 ppm SO_2 for silver maple.

Growth was suppressed for only 14 days following fumigation. Growth rate between 14 days and 28 days after fumigation was similar to the growth rate before fumigation (Fig. 3).

Figures 4 to 6 show the leaf injury caused by the high doses of fumigation. Injury increased significantly for all species with an increase in SO_2 concentration, in length of exposure, and in dose (concentration × time).

In general, growth reduction was inversely correlated with an increase in leaf injury. For example, with yellow-poplar, as the concentration of SO_2 increased from 1 to 4 ppm, leaf injury increased from 0 to 47 percent and growth was reduced from 171 mm to 122 mm. Similar relationships were observed with eastern cottonwood and silver maple.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 1. Height growth response of six woody species fumigated with 0.25 ppm sulfur dioxide. C—control, F—fumigated.

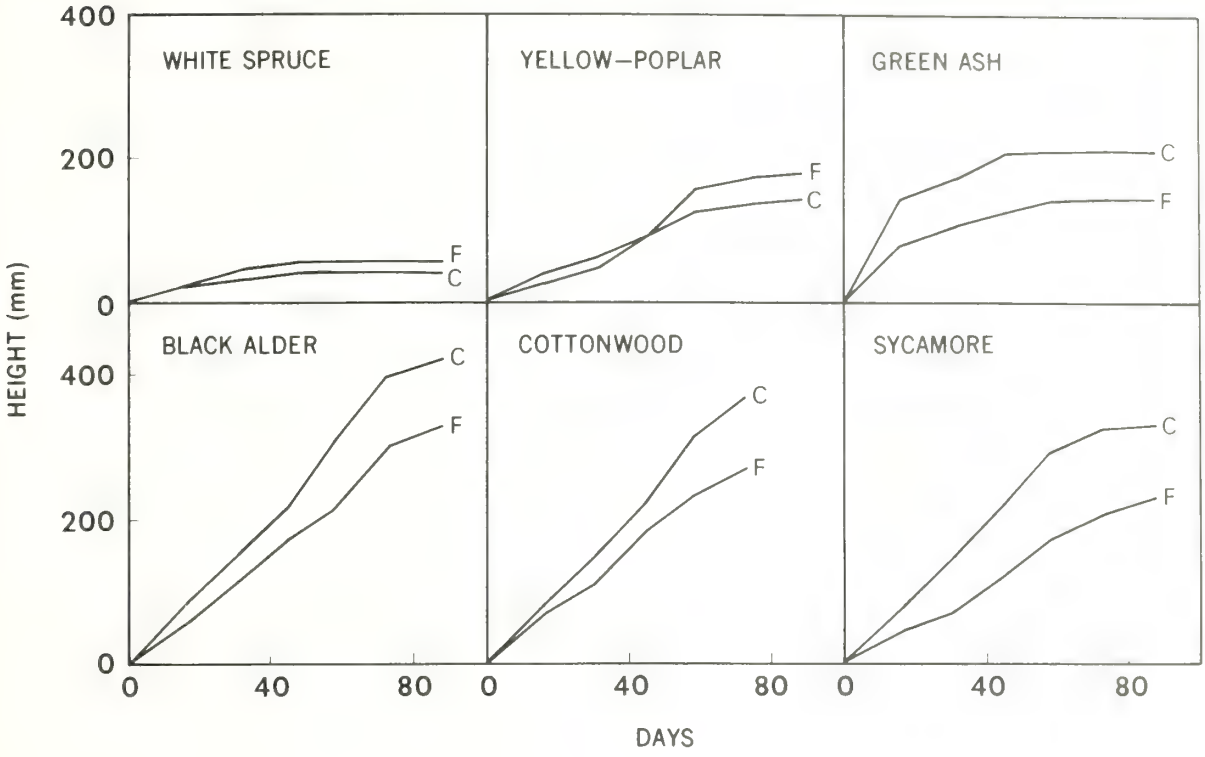
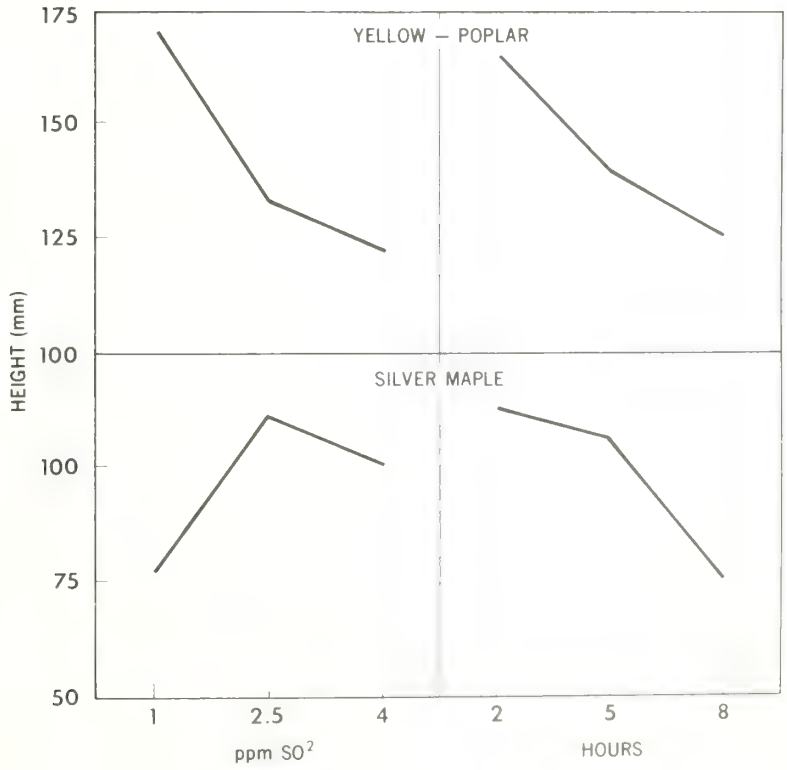


Figure 2. Height growth of silver maple and yellow-poplar seedlings fumigated with toxic doses of SO_2.



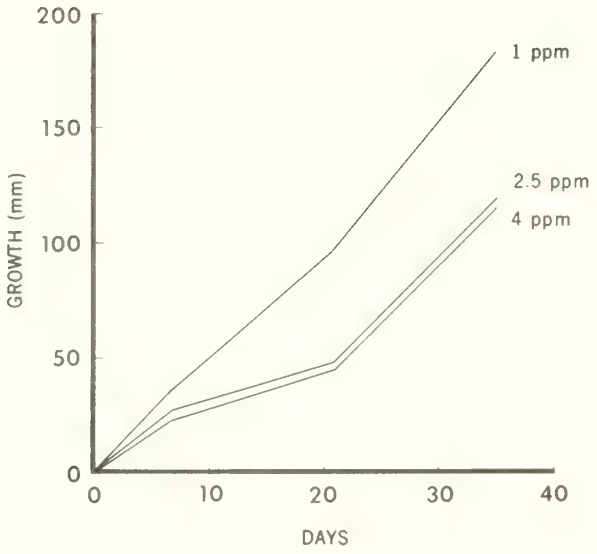
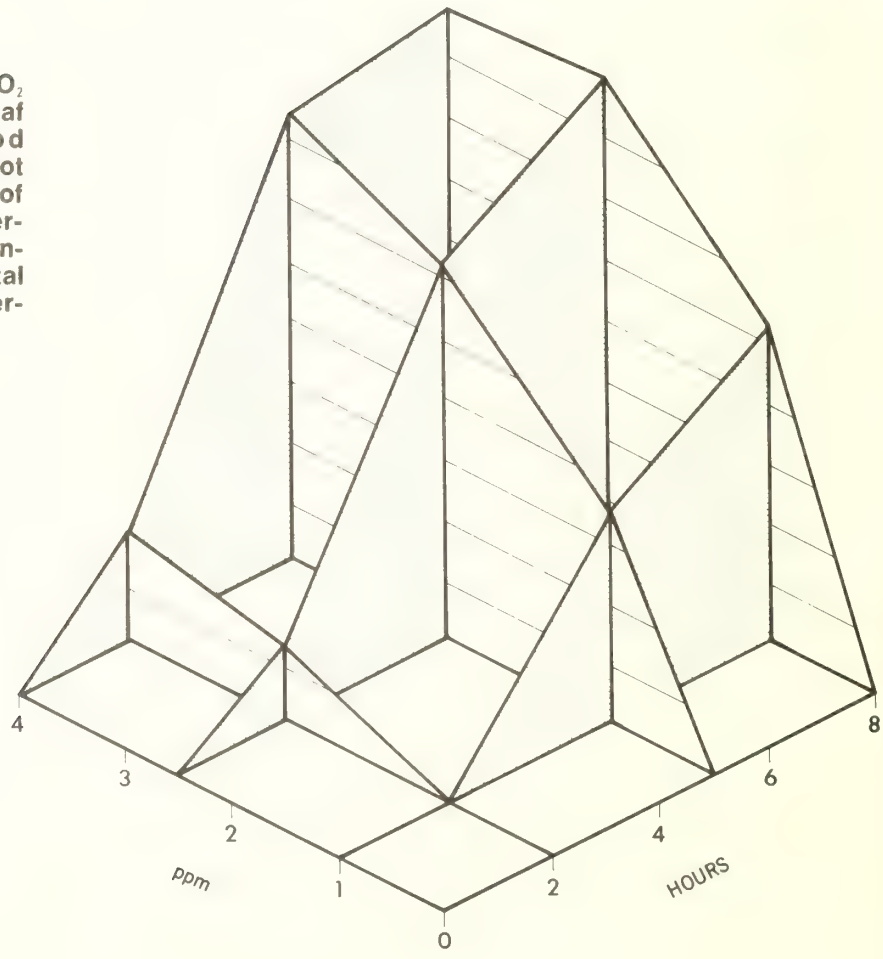


Figure 3. Growth pattern of yellow-poplar seedlings fumigated for 5 hours with toxic levels of SO_2. Fumigation treatments were applied on the seventh day.

Figure 4. Effect of SO_2 fumigation dose on leaf injury of cottonwood seedlings. Graph is a plot of the percentage of leaves with over 50 percent of the surface injured. Each horizontal line represents 10 percent.



Jensen, Keith F., and Leon S. Dochinger.
1979. **Growth responses of woody species to long- and short-term fumigation with sulfur dioxide.** Northeast. For. Exp. Stn., Broomall, PA
7 p. illus. (U.S. Dep. Agric. For. Serv. Res. Pap. NE-442)

Height growth of silver maple, white ash, yellow-poplar, sycamore, eastern cottonwood, and white spruce seedlings was not significantly influenced by 0.15 ppm SO_2 for 8 hours/day, 5 days/week. A fumigation treatment of 0.25 ppm SO_2 for 8 hours/day, 5 days/week didn't significantly affect height growth of black alder, yellow-poplar, or white spruce seedlings but significantly reduced the height growth of eastern cottonwood, green ash, and sycamore seedlings. Exposure to toxic concentrations of SO_2 (1 to 4 ppm) for 2 to 8 hours significantly affected the height growth and caused leaf injury in silver maple and yellow-poplar seedlings. Growth was only suppressed for 14 days after the toxic fumigation because by that time new leaves had formed and normal growth had resumed.

425.1, 161.4

Keywords: Air pollution, leaf growth, eastern cottonwood, sycamore, green ash.

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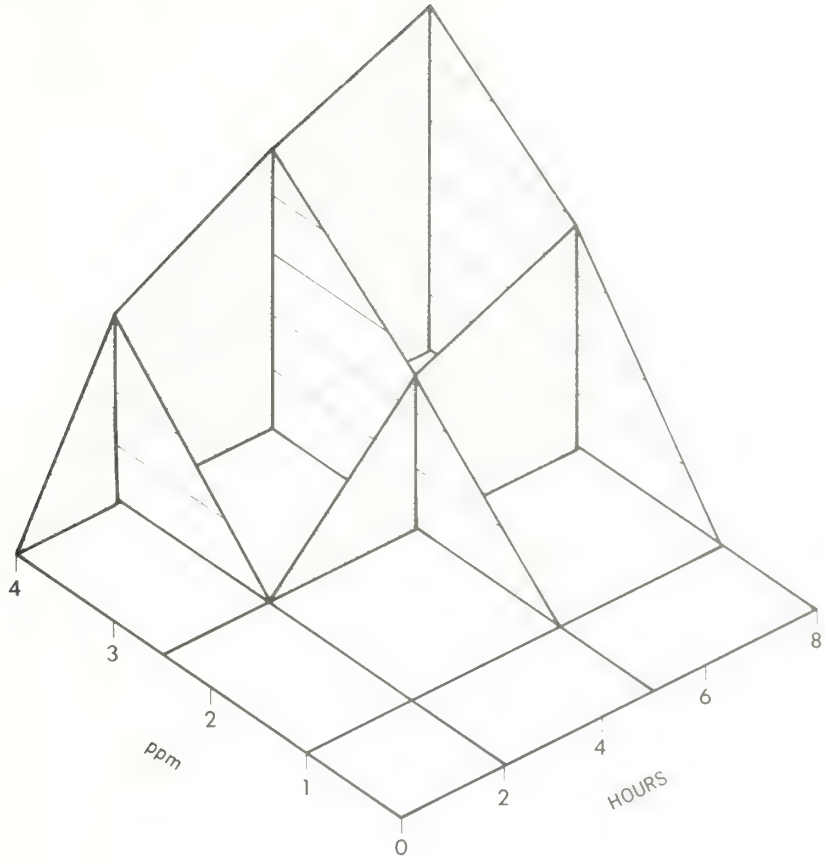
425.1, 161.4

Keywords: Air pollution, leaf growth, eastern cottonwood, sycamore, green ash.

Figure 5. Effect of SO_2 fumigation dose on leaf injury of yellow-poplar seedlings. Plotted in the same way as Figure 4.



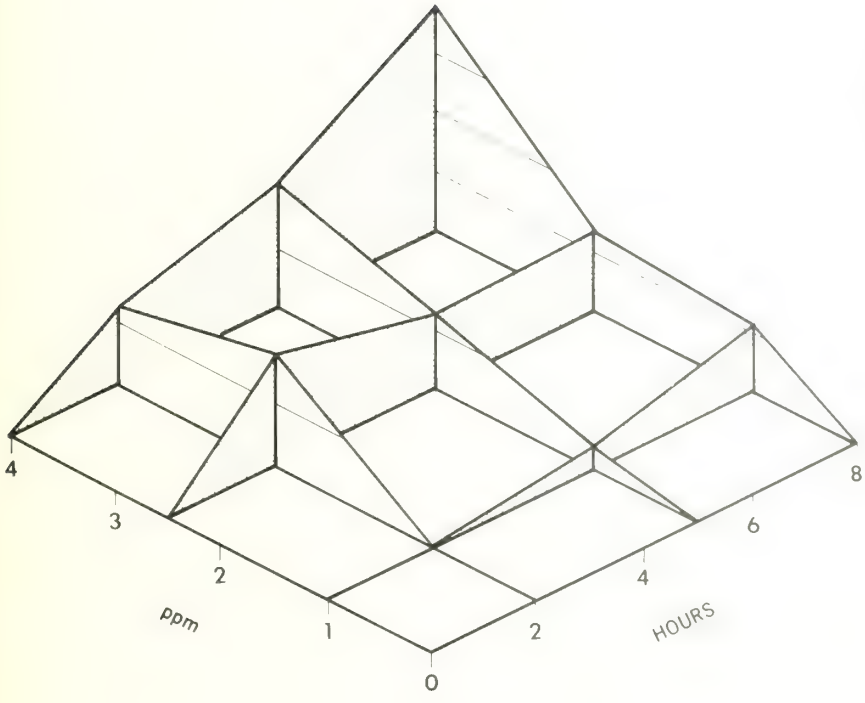


Figure 6. Effect of SO_2 fumigation dose on leaf injury of silver maple seedlings. Plotted in the same way as Figure 4.

DISCUSSION

The nonsignificant change in height of seedlings fumigated with 0.15 ppm SO_2 and of white spruce, yellow-poplar, and black alder fumigated with 0.25 ppm SO_2 suggest that many woody species are tolerant to present-day levels of this pollutant. However, caution must be exercised in making such general conclusions. In the natural environment the average concentration of SO_2 is lower than that used in these experiments and the range of concentration is wider. Also, we used only one pollutant, whereas in the natural environment several, pollutants or chemicals may be present, which in combination with even low levels of SO_2 may be harmful to plant growth (Dochinger et al. 1970, Tingey et al. 1971b, Costonis 1973, Houston 1974). Another consideration is the condition of the seedlings. In these experiments the seedlings were grown under good environmental conditions, whereas under field conditions, light, water, or some other factor may be limiting. Limiting environmental factors can modify the response of plants to pollutants (Heck and Dunning 1967, Menser et al. 1963).

The pollutants may also initiate secondary problems that would not develop in chamber experiments. The pollutants may act as a stress factor and weaken the host just as drought or frost would. After several years in this condition, the vigor of the trees may decline and the trees may become susceptible to insect or disease attack (Cobb and Stark 1970).

The reduction in height of seedlings fumigated with 0.25 ppm SO_2 was due to a reduced growth rate. The average growth rate for green ash, eastern cottonwood, and sycamore seedlings dropped from 3.6 mm/day in the control chamber to 2.5 mm/day in the fumigated chamber. These reductions in height were associated with a reduction in number of leaves. It was significant only for eastern cottonwood, but the trend of fewer leaves with less growth must certainly be considered. With more leaves, more photosynthate should be available for growth. Additionally, the pollutant may suppress the photosynthesis rate (Bennett and Hill 1973, Sij and Swanson 1974). This may explain why no significant differences were found between treatments in height of yellow-poplar seedlings even though the seedlings in the fumigated treatment had a significantly higher number of leaves.

The high levels of SO_2, 1, 2.5, and 4 ppm, had no influence on height growth until the exposure time exceeded 2 hours. After 5 and 8 hours, growth of silver maple and yellow-poplar was statistically reduced. A reduced growth rate was observed only for 2 weeks after fumigation as by the 4th week the growth rate was again comparable to the rate before fumigation. New leaf tissue had been formed to replace the leaf tissue destroyed by fumigation.

The analysis of leaf injury using response surfaces was suggested by Temple (1972). This approach allows an analysis of exposure and concentration both independently and jointly. With eastern cottonwood, injury tended to increase as the length of fumigation increased, whereas with yellow-poplar and silver maple, injury tended to increase with increased pollutant concentration. Foliar injury of all three species increased as dose increased.

To compare SO_2 susceptibility ratings at high and low fumigation levels, silver maple, eastern cottonwood, and yellow-poplar were ranked according to sensitivity, from their response in experiment 1, 0.25 ppm, and experiment 3, toxic levels. In experiment 3, eastern cottonwood and yellow-poplar were classified as more sensitive than silver maple on the basis of foliar injury, and eastern cottonwood more sensitive than yellow-poplar on the basis of height growth. In experiment 1, eastern cottonwood was again classified as more sensitive than yellow-poplar on the basis of height growth. No comparison can be made with silver maple as no differences were found with the 0.15 ppm fumigation and no seedlings were available when the 0.25 ppm SO_2 fumigation experiment was established. These results are encouraging in that classification schemes for low levels of SO_2 can be developed from experiments that use toxic levels of pollutants, but many more studies are needed before definite relationships can be established.

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INHERITANCE OF COMPARTMENTALIZATION OF WOUNDS in Sweetgum (*Liquidambar styraciflua* L.) and Eastern Cottonwood (*Populus deltoides* Bartr.)

by P. W. Garrett, W. K. Randall, A. L. Shigo and W. C. Shortle

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Abstract

Studies of half-sib progeny tests of sweetgum (*Liquidambar styraciflua*) and clonal plantings of eastern cottonwood (*Populus deltoides*) in Mississippi indicate that rate of wound closure and size of discolored columns associated with the wounds are both heritable traits. Both are independent of stem diameter, which was used as a measure of tree vigor in these studies. Selection for rate of closure would not be useful, but selection for compartmentalization of discoloration and decay resulting from wounding would be valuable in forest and amenity trees and could be applied immediately to existing improvement programs for these species.

INTRODUCTION

MOST PLANT BREEDING programs emphasize improved yield. In some instances resistance is sought to insects or diseases that either kill the host or produce visible damage. For annual crops these may be the most important goals, but for perennial plants, including trees, the long cycles present some unique problems that will require some unique approaches to improvement. We are talking about organisms that produce *internal* discoloration and decay that only becomes apparent when the tree is felled.

Some recent estimates of cull in northern hardwood stands indicate a volume loss of between 25 and 35 percent (Schmitt et al. 1978). Similar estimates for hardwood stands in North Carolina have been published (U.S. Forest Service 1976). There may be some disagreement about methods used to derive these figures, but no one who has looked at these stands would question the fact that considerable losses are occurring.

Wounds of all types, including branch stubs, are the principal infection ports where the processes leading to infection, wood discoloration, and eventually decay in living trees start. Previous wounding studies have concentrated on rate of callus formation and wound closure, and for many years closure and "wound healing" were almost synonymous. But the ability of the tree to cope with external damage is much more complex than that, and, in fact, may not be related to closure at all. If we accept the medical definition for healing, "restored to the original condition," then plants do not heal wounds. While it is true that trees may physically seal off and overgrow visible wounds, it appears that there are at least two internal defense mechanisms that start to operate when wounding occurs. There are chemical barriers that keep out most wood-destroying microorganisms, and to combat those organisms that do manage to get by the first line defenses, trees have another system for walling off or confining the area of infection. This second system has been labeled 'compartmentalization' (Shigo 1972).

Artificial wounds made in red maple and American elm to study the progression of discoloration and decay showed that some trees compartmentalized wounds more rapidly than others (Shigo and Wilson 1977). Other studies with clones of *Populus deltoides* × *P. trichocarpa* suggested that closure and compartmentalization might be under genetic control (Garrett et al. 1976, Shigo et al. 1977a, Shigo et al. 1977b). If it is possible to select trees that are strong compartmentalizers, and if this trait is heritable, then wound-resistant trees could be bred. They would find immediate application in the nursery trade and could be equally important in tree improvement programs for reforestation.

Two things are essential for this to work. The first is a nondestructive method of determining response to artificially induced wounds in trees that are to be preserved as parental stocks in seed orchards. The Shigometer, which requires only a 2.4 mm (diameter) hole, enables us to differentiate between healthy and discolored or decayed wood associated with wounds (Shigo 1974). The other essential is that disease resistance by compartmentalization be a heritable trait that can be incorporated into a breeding program. Heritability was tested using half-sib families of *Liquidambar styraciflua* L. (sweetgum) and clones of *Populus deltoides* Bartr. (eastern cottonwood). The results of those tests are summarized in this paper.

MATERIALS AND METHODS

Sweetgum

A 12-year-old one-parent progeny test of sweetgum involving 81 families collected in the lower Mississippi Valley from Tennessee to the Gulf Coast was used for this study. Forty-four families are from parents selected for phenotypic superiority and 37 are random selections. Ten replicates were planted on the Delta Experimental Forest near Greenville, Mississippi, in a 9 × 9 balanced lattice design. Survival was good and early growth of seedlings from the random selections was as good as from the superior phenotypes.

One tree in each replicate of each family was selected for treatment. Each tree received four wounds: two at 0.5 meters above ground level and two at 1.0 meters. Wounds were 180 degrees apart at each level and 90 degrees apart between levels. A power drill was

used to make a wound approximately 2 centimeters in diameter and 3 centimeters into the stem. Wounding was completed in mid-March 1976, before the growing season had begun.

Early wound closure was recorded in mid-June and wounded trees were cut in early October. Cross-sectional discs thick enough to include all discoloration were taken from each wounding level. Late wound closure measurements were taken and then discs were cut vertically through the wounds on a bandsaw to expose any internal discoloration or decay resulting from the treatment.

Genetic, phenotypic, and environmental correlations were calculated; estimates of the variance components were obtained by the

Figure 1.—Radial view of two trees representing different half-sib families of sweetgum showing extremes of compartmentalization of discoloration associated with artificially induced wounds.

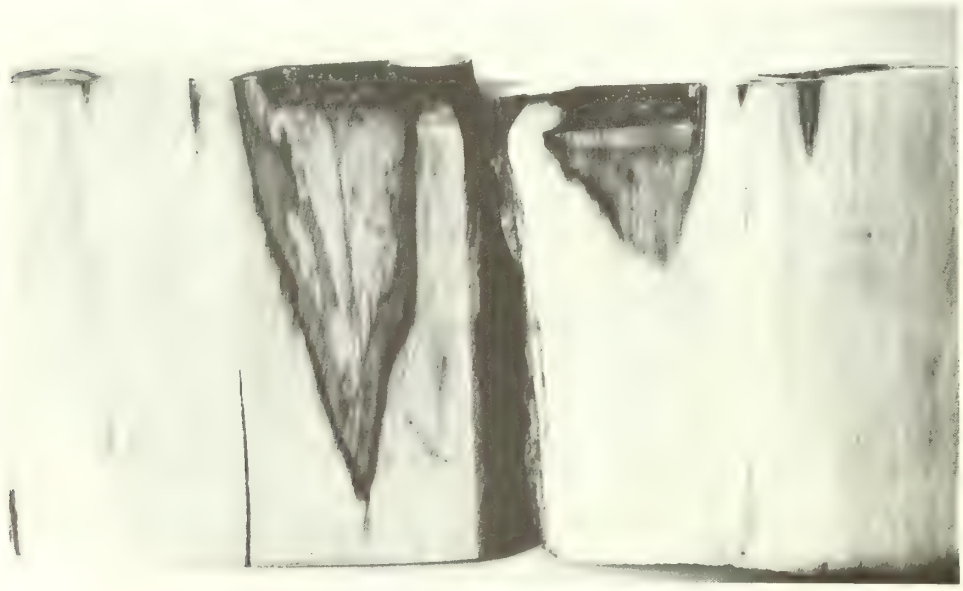
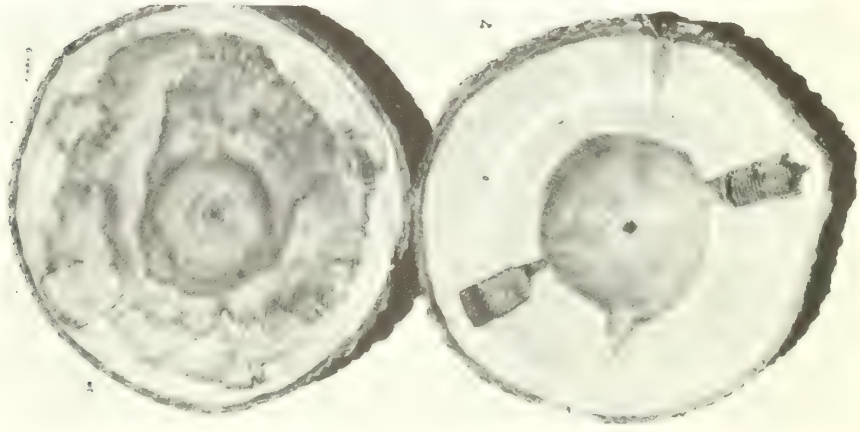


Figure 2.—Transverse view of two clones of eastern cottonwood showing wounds, wound closure, and the degree of discoloration associated with internal compartmentalization.



Garrett, P. W., W. K. Randall, A. L. Shigo and W. C. Shortle.
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Studies of half-sib progeny tests of sweetgum (*Liquidambar styraciflua*) and clonal plantings of eastern cottonwood (*Populus deltoides*) in Mississippi indicate that rate of wound closure and size of discolored columns associated with the wounds are both heritable traits. Both are independent of stem diameter, which was used as a measure of tree vigor in these studies. Selection for rate of closure would not be useful, but selection for compartmentalization of discoloration and decay resulting from wounding would be valuable in forest and amenity trees and could be applied immediately to existing improvement programs for these species.

443.3:165.53 + 176.1 *Liquidambar styraciflua* L. + 176.1 *Populus deltoides* Bartr.

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analysis of variance method, and heritability was estimated from them for wound closure, discoloration, decay, and tree size.

Cottonwood

A 7-year-old clonal test of eastern cottonwood was selected for this study. Four cuttings each of 59 clones were planted in 5 replicates at Huntington Point near Greenville, Mississippi. A 12 × 12 foot square plot was used and the trees received the standard cottonwood care on these bottomland sites.

Early survival was variable, as expected, with an average for the planting of 66 percent. Growth was also variable, with a mean diameter at age 5 of 7 inches (5.3 to 9.1 inches). The larger clones averaged slightly more than 11 inches by age 7. The same number of wounds were applied in the same configuration as in the sweetgum.

Early wound closure was recorded in mid-June and trees were cut in early October. Cross-sectional discs were cut, and diameter of stems (inside bark) and diameter of discolored columns were recorded.

RESULTS AND DISCUSSION

We had already found that individual trees within a species responded differently to the same level of artificial wounding. What was not known was whether compartmentalization of wound tissue was a heritable trait that would be useful in breeding programs. This study with half-sib material provides conclusive evidence that it would be possible to incorporate this additional trait into a selection program with sweetgum.

The heritability estimates for early closure, discoloration (combined) and decay (combined) are the most interesting traits, and the last two indicate that gains could be achieved through a selection program (Table 1).

By the end of the growing season wound closure of even the slowest closing trees had progressed to nearly the same stage as that of the more active trees. If closure were an important factor in limiting internal decay processes, one would expect that rapid closure would be desirable and negatively correlated with discoloration and decay. In fact, these traits were not significantly correlated, suggesting that even the most rapid rates observed in sweetgum are not sufficient to prevent the entry of the ubiquitous disease organisms.

Heritability figures for discoloration of wood above the wound were very high; those for combined measurements were still fairly high; but those for areas below the wounds were not significantly different. Discoloration was positively correlated with decay but negatively correlated with total stem diameter at 1.0 meters. We did not record the width of the last ring, or the most recent set of rings; consequently, we are using total tree size as an indication of vigor. We recognize the possibility that growth of individuals differs and that some trees may have gotten off to a slow start before entering a period of faster growth. The end result of this would be two trees with the same current diameter but entirely different current growth patterns. The sampling procedure used in this study and the results

Table 1.—Estimates of heritability

Trait	Heritability—plot means	
	Sweetgum	Cottonwood
Early closure	1.59	0.74
Late closure	0.00	
Discoloration above wound	1.67	
Discoloration below wound	0.59	
Combined discoloration	1.51	
Decay above wound	1.05	
Decay below wound	1.17	
Combined decay	1.38	
Diameter column/diameter tree		0.69

Equations for estimating heritability:

$$h^2 \text{ (sweetgum)} = \frac{4\sigma}{\sigma_{\quad} + \frac{1}{R}\sigma}$$

$$h^2 \text{ (cottonwood)} = \frac{\sigma}{\sigma + \frac{1}{R}\sigma}$$

obtained suggest that our analysis is essentially correct and that in fact there is no correlation between rapid growth and wound closure, discoloration, or decay.

Growth rate for cottonwood, and especially in this planting, is exceptionally fast and wounds closed very rapidly. Many wounds were closed by the first recording period in June, and all but a very few were completely sealed by October when the discs were cut.

While the numbers are generally smaller than with sweetgum, the heritability estimates for early closure and diameter of discoloration columns indicate that both are under genetic control, so discoloration could be minimized in a tree improvement program (Table 1). Wound closure was extremely rapid in this species and was not significantly correlated with diameter of the discoloration columns.

CONCLUSIONS

Earlier experiments using a variety of wound dressings on red maple and American elm indicated that treatment of trees immediately after wounding did not help contain decay and discoloration in the stem. Treated and untreated trees reacted similarly (Shigo and Wilson 1977).

The results of our studies and the earlier work with wound dressings are conclusive proof that it is the act of opening the tissue for colonization by disease organisms and not the rate of closure that is important. Once the wound is made, by whatever means, the inheritant capacity of the tree to compartmentalize the affected tissue will decide how much discoloration and decay will result.

While the numbers were generally smaller in cottonwood than in sweetgum, the heritability estimates for early closure and diameter of discoloration columns indicate that both are under genetic control; again, the second parameter would be useful in a tree improvement program.

The differences in column size in cottonwood were much more spectacular even though the heritability figures are slightly smaller. The ratio of discolored column to stem diameter (inside bark) ranged from 38.2 to 79.2, a difference of 41 percent.

Differences in column size in sweetgum were significantly different; however, the actual differences in family means were only 5.5 centimeters (column above the wound). It should be pointed out that the wound size used in these studies was small in comparison to the natural and man-caused wounds that trees are regularly subjected to, and the larger the wound, the larger the column. While the relative differences may be the same for wounds of different sizes, the actual differences will be substantial.

From this and earlier studies it seems obvious that a new and useful tool has been found, one that can be immediately applied in existing improvement programs where a number of select trees have already been identified. Trees that are now included because of size, volume, branchiness, wood density, insect resistance, etc., can be wounded and their response checked with a Shigometer as one additional selection criterion.

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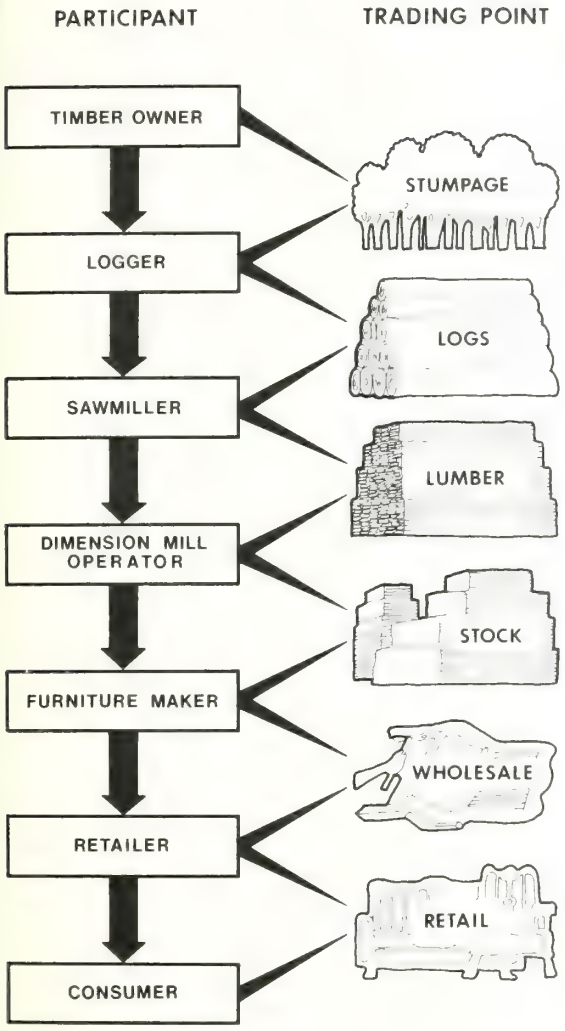

MARKETING LOW-GRADE HARDWOODS FOR FURNITURE STOCK — A NEW APPROACH

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by Hugh W. Reynolds
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Abstract

A hardwood shortage of high-grade lumber exists while there is a surplus of low-grade hardwood timber. Two things are needed for the surplus to correct the shortage: a new manufacturing system and a new marketing technique. Utilization research at the Princeton Forestry Sciences Laboratory has developed the new system for converting low-grade hardwood for furniture use. The manufacturing steps can be integrated with the existing marketing system from the timber grower to the logger to the sawmiller to the dimension maker to the furniture producer.

INTRODUCTION

FURNITURE PRODUCTION is increasing. Standard hardwood lumber shipments are not. Hardwood lumber prices are rising. Furniture prices are not rising as fast as lumber prices. These four facts suggest to even the most casual observer contradictions that the furniture industry cannot absorb indefinitely. However, consider a fifth fact: while there is a shortage of the highest grades, there is no shortage of hardwood timber in general. Hardwood growth is greater than hardwood harvest.

What is the problem, then? The problem of furniture makers is how to use abundant low-grade hardwood to supplement the scarce high grades. And, they must do this in a way that will be of value to the timber grower, the logger, and the sawmiller as well. We believe that this report suggests a viable solution to the problem of how to use low grades in furniture.

MARKETING HARDWOODS FOR FURNITURE TODAY—A BRIEF GENERALIZATION

There is a lot of buying and selling going on as high-grade hardwood timber is converted into furniture and sold to the final consumer (Fig. 1). We identify six major trading points:

1. "Stumpage"—A timber owner sells standing timber to a logger for a stumpage fee.
2. "Logs"—The logger sells logs from the timber he has cut to a sawmiller.
3. "Lumber"—The sawmiller sells lumber to the dimension mill owner or a furniture maker. In some places brokers assist in moving lumber from the sawmill to the user.
4. "Stock"—The lumber is dried, processed into rough part sizes, and sold to the furniture maker by the dimension mill owner. When the lumber is sold directly from the sawmill to the furniture maker, the "stock trading point" becomes an internal bookkeeping function of the furniture plant.
5. "Wholesale"—The furniture maker sells his product to a retail store.
6. "Retail"—The retailer sells furniture to the ultimate consumer.

Consider the first three trading points. While each has a serious effect on the fourth or "stock" trading point, each is usually independent. Neither the timber owner nor the logger knows or is concerned about the final use of the wood. Although the logger's bucking decisions affect the maximum length of a rough part, his major concern is maximizing his profit when he sells his logs to the sawmill. The sawmiller, in turn, wants to saw as precisely as possible and produce as much high-grade lumber as possible. How the lumber is to be used is beyond his area of interest. When the woods were full of large high-quality trees, these procedures and objectives were adequate.

The wholesale and retail trading points need not be considered further here. Furniture stock sawed from high-grade timber and furniture stock sawed from low-grade timber to the same quality standard will look and behave the same.

MARKETING LOW-GRADE TREES FOR FURNITURE USE—A NEW APPROACH

Low-grade timber is not what the forester sets out to grow. He wants high-grade timber. Unfortunately, most of the hardwood acres have not been managed by foresters. Instead, most of the hardwood stands are the result of nature's growing technique followed by indiscriminate cutting. An area is saturated with a tremendous number of seedlings. As these miniature trees grow to saplings, to poletim-

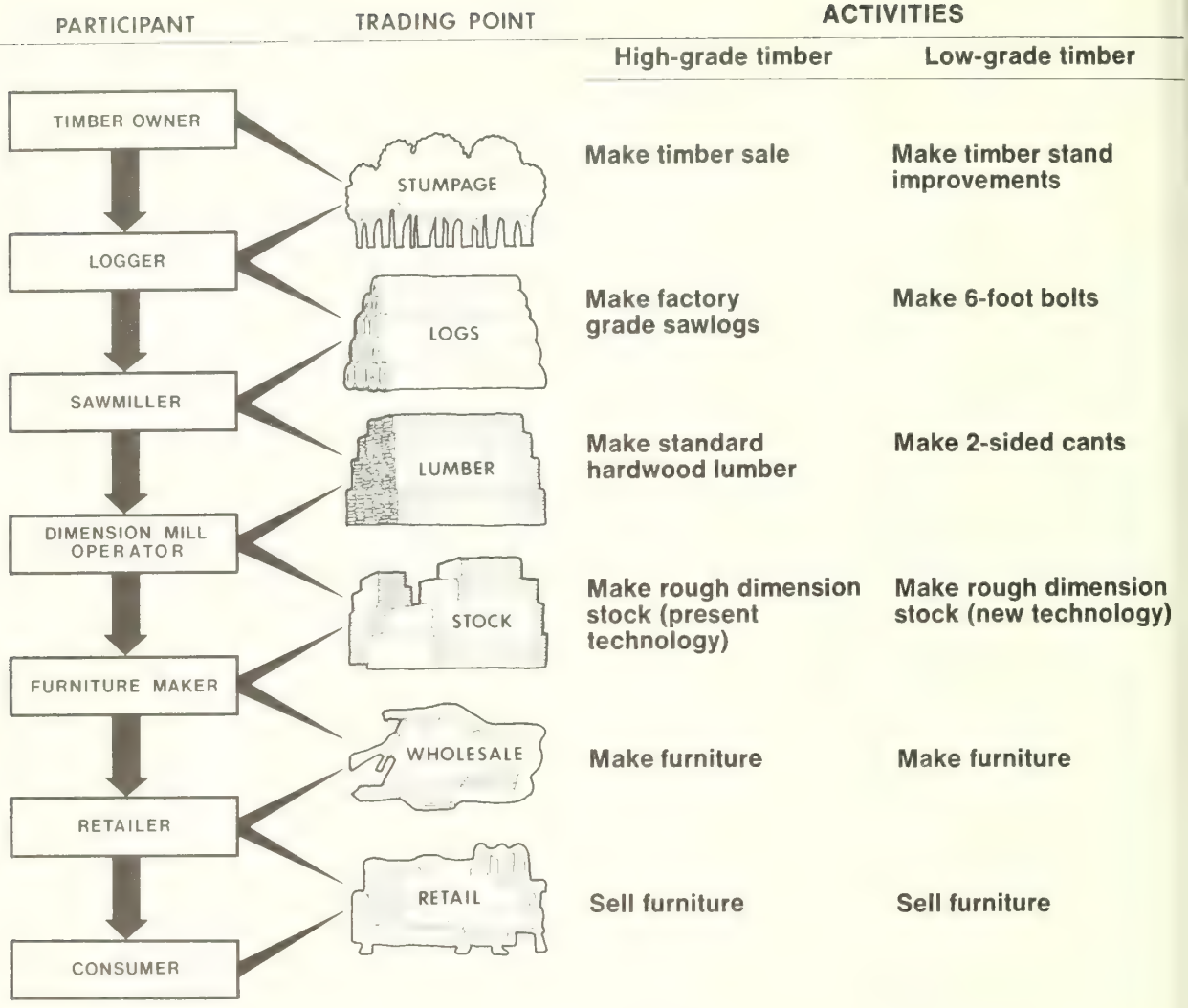

Figure 1.—Marketing hardwoods: trading points from hardwood timber to furniture.

ber, and finally to sawtimber size, most of the trees must die as there is room for only a few. In this way the "best" trees compete and survive. But this way is not very efficient. Often we find acres of small trees in a stagnant situation with no forester's attention being applied. Conventional hardwood markets do not provide enough economic incentive to remove the excess small low-grade timber so that the best forestry practices can be applied.

We feel that the low-quality, small-diameter hardwood forest can best produce pulp, pallets, and parts for furniture. If we include the residue from sawing operations, there is an important fourth product: energy. In any event, it is not what is in the forest that is most important; rather, it is how to get the products out of the small-diameter, low-grade trees. Years of research at the Forestry Sciences Laboratory lead us to recommend a new way.

The key to our low-grade hardwood marketing method is to use the best of the low-grade trees for furniture parts, with the remainder going to pallets, pulp chips, and/or energy. The low-grade trees will be harvested as bolts. The bolts will be sawed to cants instead of to

conventional lumber. Cants will be sawed to short boards which will be made into rough dimension stock. Let us look at this in greater detail.

The "stumpage" trading point

About half of the hardwood volume is in tree stems 12 inches or less in diameter. A program geared to process logs up to 12 inches in diameter provides an excellent opportunity for timber stand improvement (TSI)—the removal of excess trees. Traditionally, the forester has a logger remove these trees, gives him the wood he removes, and pays him in addition. This work is done on the theory that the remaining forest will ultimately pay this cost. Contrast this with high-grade timber sales, in which the logger pays the forester "stumpage" for everything he cuts.

With our new approach to processing, we believe the value of the low-grade timber will be high enough overall to eliminate the need to pay the logger for TSI work. While we do not envisage a lucrative stumpage for the timber owner, improving his forest at no cost or even a small profit should be attractive.

Our approach to stumpage is to set the value of the best of the low-grade hardwood timber equal to the cost of the remaining TSI work. In this way, the forester (seller) will get the TSI that is required to grow high-grade hardwood timber without an out-of-pocket investment. The logger (buyer) will have low-grade timber to sell at a price that will allow him a reasonable profit.

The "logs" trading point

Sawmill machinery is inflexible. Its main purpose is to generate a flat surface parallel to another flat surface. To this machinery we feed round or somewhat round logs that may be crooked, heavily tapered, or otherwise less than perfect cylinders. Some "tailoring" of the tree-length stem must be done to accommodate the sawmill's requirement for straightness.

With low-grade hardwoods, a compromise between log length and log quality must be made. By cutting out the poorest sections, higher grade bolts can usually be bucked from low-grade trees. However, there is a limit to how much grade improvement can be expected. Low-grade hardwood trees are not only knotted and of indifferent quality, they are often crooked, too.

Making very short bolts, 4 to 5 feet long, takes a lot of work and requires a lot of handling. There does not appear to be enough yield to justify using such short initial lengths. On the other hand, bucking to 8-foot lengths that are fairly straight is less work and the quality level is good. The only problem is that there are not many of these 8-foot lengths available.

We have found the best compromise of bolt length and parts quality and quantity (or yield) to be reached when 6-foot-long bolts are bucked from tree length stems (Reynolds and Schroeder 1978). Fortunately, most furniture stock parts are short, so the 6-foot length is not a deterrent.

A compromise of bolt diameter limits is also required. Sawmill machinery that can saw very large bolts makes a wide, wasteful headrig kerf. And, bolts whose diameters are very small have a large percentage of juvenile wood which is weak and which causes sawing and drying problems. By limiting the bolt range to 7.5 through 12.5 inches in diameter, the juvenile wood problems are reduced and oversize sawmill equipment is not required. About half of all hardwood growing stock is in this diameter range.

In our new approach to marketing low-grade hardwood logs for furniture use, the logger will make and sell 6-foot-long bolts, 8 to 12 inches in diameter (small end), from the better low-grade hardwood tree length stems.

The "lumber" trading point

It is a rule of thumb that hardwood sawmills make a profit on 1 Common and Better lumber but do well to break even on 2 Common and poorer lumber. When factory grade 3 logs up to 12 inches in diameter are sawed to lumber, very little 1 Common and Better lumber will be made. Therefore, very little if any profit will be made if only the best of the low-grade logs are sawed to lumber. It is easy to see that a different sawn product will have to be made if the sawmill is to make a profit.

Rather than lumber, we recommend that the sawmiller convert the bolts to cants. Bolts

can be sawed very efficiently to cants with specialized Scragg-type sawmills. The sawmiller can afford to sell the cants at a lower price per board foot than he would have to charge if he sawed the bolt into lumber. In addition, all of the cant will be sold at one time. The sawmiller will not have to grade, sort, and sell lumber by grade.

The "stock" trading point

New rough mills to make rough furniture dimension stock from cants have been designed. The cants are resawed to boards and the boards are dried. Then the boards are crosscut to stock lengths, edged, and planed in one operation. At this point, many of the pieces are ready to be used directly. The other pieces will be further processed to remove defects. If some of these pieces will require too much manual processing, they will be discarded and used for fuel.

If parts are needed in longer lengths than are available, Serpentine end matching (Sem) (Gatchell, Coleman, and Reynolds 1977) may be used to glue short stock lengths to the required longer lengths. These long lengths may be edge-glued into wider parts or panels.

Once the rough dimension stock has been produced with these new approaches, it can be sold (or used) in direct competition with rough dimension made from standard hardwood lumber that has been processed with traditional technology. The two rough dimension stock products are made to the same quality standards. Only the raw material and the manufacturing process will be different. Because the dimension mill operator uses a relatively inexpensive raw material that has been specifically tailored to fit his new-technology process, he can match the price charged for conventionally produced stock and make a profit.

THE NEW APPROACH—CAN IT WORK?

Whether the new marketing approach will be successful depends mainly on whether equal products can be delivered at prices similar to those of conventional products. An important question is whether each step in the marketing processing chain benefits people enough to make a change worthwhile. Let us illustrate the new approach with results from a black cherry study that was conducted as part of a TSI effort in West Virginia.[1] The end product was furniture that was commercially finished and appraised.

The end product must carry the costs and profits of all that goes before. Because the rough dimension stock produced conventionally and that produced by the new techniques are equal in all respects, we can start at the stock trading point and work back to the forest. In this example, we will consider only the value of the furniture parts and not other possible products such as chips or energy.

Pricing at the stock trading point by the furniture maker

Most furniture makers have rough mills where standard hardwood lumber is manually converted to rough dimension parts. Determining the value of these parts is generally done with rules of thumb: Using 1 Common lumber, one-half of the raw material will end up in parts, and the value of rough parts is equal to twice the cost of the lumber input.

On a 4/4 basis, it will take 2,000 board feet of lumber to make 1,000 square feet of rough dimension parts. In mid-1978, the average price for 1 Common black cherry lumber was $575 per Mbf (thousand board feet). At a 50 percent yield, it will take $1,150 worth of lumber to make the 1,000 square feet of dimension stock. The value of these parts is twice the cost of the lumber input or $2,300 per thousand square feet.

The furniture maker will consider purchasing rough dimension parts if the price of these parts is equal to or less than the value of the parts made in his own rough mill. As the rough parts from the new procedures are equal in all respects to those produced with conventional technology, we set the price of the new method parts to the same $2,300 per thousand square feet.

[1]Reynolds, Hugh W. System 6: Black cherry lumber yield from thinnings. (Unpublished report on file at Forestry Sciences Laboratory, Princeton, WV.)
Reynolds, Hugh W. System 6: Cherry furniture panels from a gang rip single length rough mill. (Unpublished report on file at Forestry Sciences Laboratory, Princeton, WV.)

Reynolds, Hugh W., and Charles J. Gatchell.
1979. **Marketing low-grade hardwoods for furniture stock—a new approach.** Northeast. For. Exp. Stn., Broomall, Pa.
7 p., illus. (USDA For. Serv. Res. Pap. NE-444)

A hardwood shortage of high-grade lumber exists while there is a surplus of low-grade hardwood timber. Two things are needed for the surplus to correct the shortage: a new manufacturing system and a new marketing technique. Utilization research at the Princeton Forestry Sciences Laboratory has developed the new system for converting low grade hardwood into furniture. The manufacturing steps can be integrated with the existing marketing system from the timber grower to the logger to the sawmiller to the dimension maker to the furniture producer.

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Pricing at the lumber trading point by the dimension maker

With the new processing method, the dimension maker will gang rip two-sided, 6-foot cants to boards and dry and process these boards to rough parts. What can he afford to pay for these cants? Our studies on black cherry, red oak, white oak, and yellow-poplar from thinnings have shown that the new process should be very profitable if the cost of the cants is one-fourth the price of the dimension parts produced, rather than one-half as with the conventional lumber. Low grade hardwoods are, after all, low grade and yields are poorer. So the dimension maker will pay $575 (one-fourth of $2,300) for enough cants to make a thousand square feet of 4/4 dimension stock.

Measuring 6-foot, two-sided cants can present a problem or two. They are curved on two sides and often tapered (Fig. 2). Their volume cannot be determined as easily as can the volume of four-sided cants. And yet, a board foot volume is needed as a marketing tool. Our technique for measuring the volume of two-sided, 6-foot-long cants is simply this: Measure the widest face on the small end of the cant and multiply this width in inches by 1½ when measuring 3-inch-thick cants, 2 when measuring 4-inch-thick cants, and 3 when measuring 6-inch-thick cants.

The yield of rough dimension parts from two-sided cants, measured this way, is roughly 30 percent. So, 3⅓ Mbf of cants are needed to produce 1,000 square feet of 4/4 stock. Recalling that the dimension maker can make a profit if he pays about $575 for enough cants to make this 1,000 square feet of parts, the price for two-sided cants is $175 per Mbf.

Pricing at the log trading point by the sawmiller

Can the sawmiller make a profit selling 6-foot-long, two-sided cants at $175 per Mbf? Yes! But before we show how, we must briefly discuss the term *board feet*. Or, more importantly, how different systems measure different volumes but still use the same label: Mbf.

Moving from surface feet of dimension parts to cant volume was rather straightforward. With cants, it was necessary to invent a technique because of the half round, half flat, tapered shape of the raw material. Going from there to the round bolt involves an even bigger variation in amount.

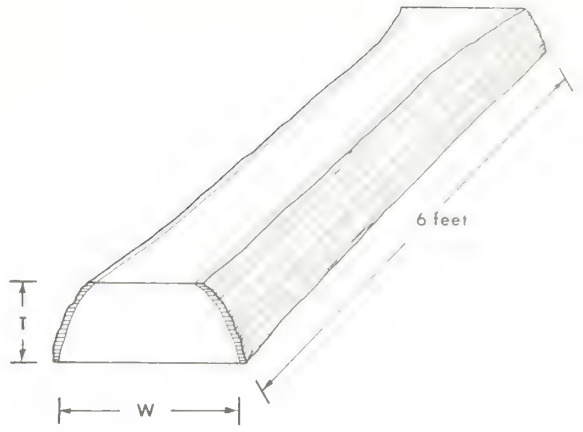

Figure 2.—Measuring two-sided cants.

T: Thickness in inches: 3, 4, or 6
W: Width in inches

$$\text{Board feet} = T \times \frac{W}{12} \times 6 \text{ feet}$$

$$= 3 \times \frac{W}{12} \times 6 = 1.5W$$

$$= 4 \times \frac{W}{12} \times 6 = 2.0W$$

$$= 6 \times \frac{W}{12} \times 6 = 3.0W$$

The commonly used measuring device for round logs or bolts is the International ¼-inch Rule. This device seriously underestimates the amount of material in small bolts. We have found that cants, measured our way, produce about 70 percent more board feet than the International ¼-inch Rule estimates. That is, 585 board feet of bolts—as measured by the International Rule—consistently produces 1,000 board feet of cants from bolts 8 to 12 inches in diameter. The 585 board feet of bolts that make 1,000 board feet of cants worth $175 have the same value as 1,000 board feet of bolts worth $300.

Is this $300 value realistic? Quite so! Let us say that the sawmiller pays $200 per Mbf for bolts. All he has to do is slab one side, turn the bolt 180°, slab the other side, and saw the bolt down the middle to make two cants. A small, circular headrig employing three men could saw two bolts per minute easily and a three-saw Scragg mill could saw three bolts per minute using only two men. For this small amount of work, the sawmiller will make $100 per Mbf of bolts over bolt costs.

Pricing at the stumpage trading point by the forester

Is the $200 per Mbf the sawmiller pays the logger realistic? We believe so. But it really depends upon the stumpage the logger must pay the forester or timber owner. Stumpage may be high (attractive to the forester) if a pulpmill or a deep coal mine is nearby. Pallet mills use a great deal of low-grade hardwood timber and pay good stumpage rates. But, many areas having low-grade hardwood timber do not have these markets. In some of these areas, stumpage rates have been as low as $1.25 per Mbf.

Consider 10 percent of the bolt selling price to be a fair stumpage price. At $200 per Mbf, a $20 stumpage price would leave the logger $180 per Mbf to cover the costs of logging, hauling, and profit. This should be attractive to the logger.

And what of the forester (or timber owner)? He wants to get TSI work done without spending any money. If the best of the 8- to 12-inch diameter timber is used for 6-foot furniture bolts, most of the TSI work will already be done. In the thinning study from which we obtained our black cherry bolts, about one-third of the timber removed for TSI was available for furniture bolts. The yield was 2 Mbf per acre of these bolts, which produced $40 per acre of stumpage value that could be used to complete the remaining two-thirds of the TSI work; that two-thirds should also produce some palletwood, pulpwood, or fuelwood. So if the forester gives the logger all of the wood in exchange for the TSI work, he will, in reality, be paying the logger $40 per acre in addition to the value of the wood for pallets, pulp, or fuel.

DISCUSSION

Having a new technology to make rough dimension stock is the first requirement for utilizing low-grade hardwood timber for furniture. A new market pricing technique is also needed that will permit the low-grade timber products to be bought and sold in the same way as products from high-grade timber. If it starts with the value of rough dimension stock produced conventionally from high-grade lumber, the new marketing technique will work.

The furniture maker sets the price he will pay for dimension stock based on the 1 Common hardwood lumber price. The dimension mill owner sells rough dimension stock at this price and determines the price of the cants he will use. The sawmiller sells at this cant price and determines the price he will pay for bolts. The logger sells at this bolt price and pays the forester (or owner) for the low-grade hardwood timber by performing TSI work.

These concepts were tested in a study of low-grade black cherry taken from a TSI cut. At the stock trading point, the selling price of rough dimension was $2.30 per square foot. At the lumber trading point, the selling price of cants was $175 per Mbf. At the logs trading point, the 6-foot bolt selling price was $200 per Mbf. The apparent discrepancy between the high bolt price and lower cant price is due to the 70 percent overrun in converting bolts to cants. At the stumpage trading point, the price was $20 per Mbf, bolt scale, which resulted in $40 per acre that the timber owner could pay, in addition to giving the smaller timber away, for the TSI work.

Is this little more than a numbers game? We hardly think so. The prices shown are conservative in comparison to those of dimension stock conventionally produced from lumber. As furniture demand increases and hardwood lumber production remains constant, the lumber prices rise rapidly; so do stumpage prices for high-quality logs. But this stumpage/lumber price pressure is not felt by the low-grade hardwood resource. So as the conventional trading point prices—stumpage, logs, lumber, stock—go up, the new-technology production using the low-grade resource will become more lucrative.

CONCLUSION

If this new marketing concept is to succeed, we must do more than prepare wood products for the next trading point in the traditional manner. A small-diameter tree that needs to be weeded out might well be used for furniture parts if all processing steps were aimed at these parts. Such trees can profitably be converted in new, specialized, highly automated rough mills. The stumpage owner, the logger, and the sawmiller should recognize this. There appears to be plenty of economic incentive for a thorough commercial test of this approach.

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RAISE cutting DIAMETERS FOR increased RETURNS

by H. Clay Smith,
G. R. Trimble, Jr.
and Paul S. DeBald

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Abstract

Diameter-limit cutting is widely used to harvest logs in eastern hardwoods. Studies show that cutting limits are often set so low that they sacrifice financial returns.

The value of lumber cut from logs is largely dependent on the diameter, grade, and tree species. As tree size increases so does the proportion of higher grade lumber, and this is reflected in improved log grades. Small trees, even though they are of sawlog size, saw out little high-grade lumber. The maximum grade log that can be obtained from a 12-inch dbh tree is a 3, which produces little quality lumber. On the other hand, a 16-inch dbh tree has the potential for producing a butt log with a grade of 1. Leaving the tree to grow from 12 to 16 inches may increase the financial value of the tree by several times. This increase in tree value with increasing tree size and grade can be expressed in annual percent value increase.

INTRODUCTION

DIAMETER-LIMIT CUTTING is probably the most widely used method of harvesting sawtimber in eastern hardwood stands. Its appeal lies in its short-range economic advantages and in that little, if any, supervision is needed if the limit is set to include all merchantable trees. Yet many foresters do not favor diameter-limit cutting as currently practiced because it results in high-grading of forest stands and lost income to the stumpage seller. We are concerned here with the latter. Diameter-limit cutting *is* often misused. Our aims are to show how and why it is improperly used, and to provide guidelines for improving its application.

The biological advantages and disadvantages of diameter-limit cutting have been thoroughly discussed in other publications (Hutnik 1958, Trimble 1971, Smith and Lamson 1977) and will not be repeated here. Rather, we will point out some of the economic implications of choosing an appropriate diameter limit by demonstrating the financial gain from leaving to grow trees that have the potential to improve their butt-log grades.

On many sawlog operations, the minimum stump diameter is set so that it approximately separates the trees that are large enough to return a profit from those so small that it does not pay to log them. To illustrate, a 14-inch stump diameter limit is one of the most commonly used guides. The reason for using this diameter limit is that a tree 14 inches on the stump (which roughly translates to 11 or 12 inches at dbh) is about the minimum size tree that will make a sawlog. Any tree smaller than this must be sold for other products of lower value, which usually are of little interest to the sawlog operator. But those who use the 14-inch stump diameter limit ignore the interrelationships among tree diameter, butt-log grade, and tree value.

Log grades are related to lumber grades and, in combination with tree volume, they provide a basis for deriving tree values. Other things being equal, the percentage of higher lumber grade improves as tree size increases. So does butt-log grade. And so does tree value. Timberland owners and foresters should be aware of these important interrelationships so that they can make intelligent choices in designating what trees to cut and what to leave in their woodlands.

METHODS

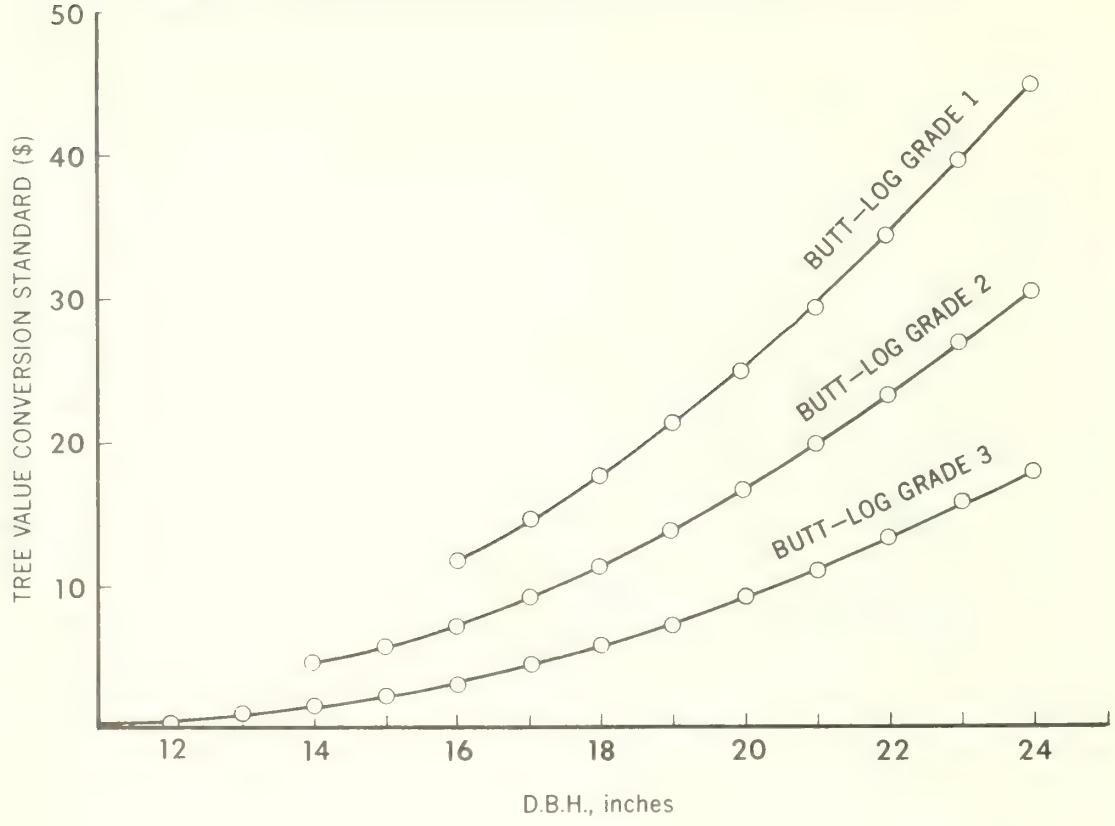
Table 1, which we condensed from *A Guide to Hardwood Log Grading* (Rast et al. 1973), summarizes the general relationships between tree diameters and butt-log grade. The diameters shown are averages; actually, diameters vary because of differences in species, site, stand density, and tree size. However, as indicated in this table, there is a generalized relationship between (1) stump diameter outside bark, measured at the height of 1 foot (2) dbh outside bark; and (3) the diameter,

Table 1.—General diameter to butt-log grade relationships.

Stump diameter (o.b.)[a]	Dbh (o.b.)	Diameter at top of butt log (i.b.)[b]	Maximum butt log grade
	Inches		*Grade*
14	11	8	3
15	12	9	3
16	13	10	3
17	14	11	2
18	15	12	2
19	16	13	1
20	17	14	1
21	18	15	1

[a]o.b. = outside bark
[b]i.b. = inside bark

Figure 1.—Tree value of 2-log red oaks by butt-log grade and dbh.



inside bark, measured at the top of the butt log—at 17 feet 3 inches above ground. These diameters are all related to butt-log grade and they determine the maximum potential grade of logs that can be sawed from the tree.

One way to emphasize the importance of the diameter-grade relationships is to point out the differences in dollar value among trees with various diameters and grades (Fig. 1). This demonstrates the financial gain from letting grow trees that have the potential to improve their butt-log grade.

In this first example we use a single species to illustrate the general trend—northern red oak (*Quercus rubra* L.). For tree values, we used the tree value conversion standards developed by Mendel, DeBald, and Dale (1976). These tree value conversion standards are similar to stumpage values, except that a percentage for profit and risk has not been deducted from them. They do, however, serve well for comparing the relative worth of trees of different sizes and log grades.

Figure 1 shows graphically for 2-log northern red oaks that the larger the tree within each butt-log grade, the higher its value. Figure 1 shows, too, the big variation in tree value within each dbh class that depends on butt-log grade. Although the relationships apply specifically to 2-log northern red oaks, the principles they demonstrate apply, generally, to all sawlog species.

Using dbh growth rate and tree value for 1-, 1½, and 2-log yellow-poplar (*Liriodendron tulipifera* L.) northern red oak, and sugar maple (*Acer saccharum* Marsh.) trees for a 10-year period, we computed increases in tree value and compared the interest rates that result, based on 10 years of additional growth and assuming that each tree would attain the maximum butt-log grade possible for its size (Table 2). Growth data were taken from

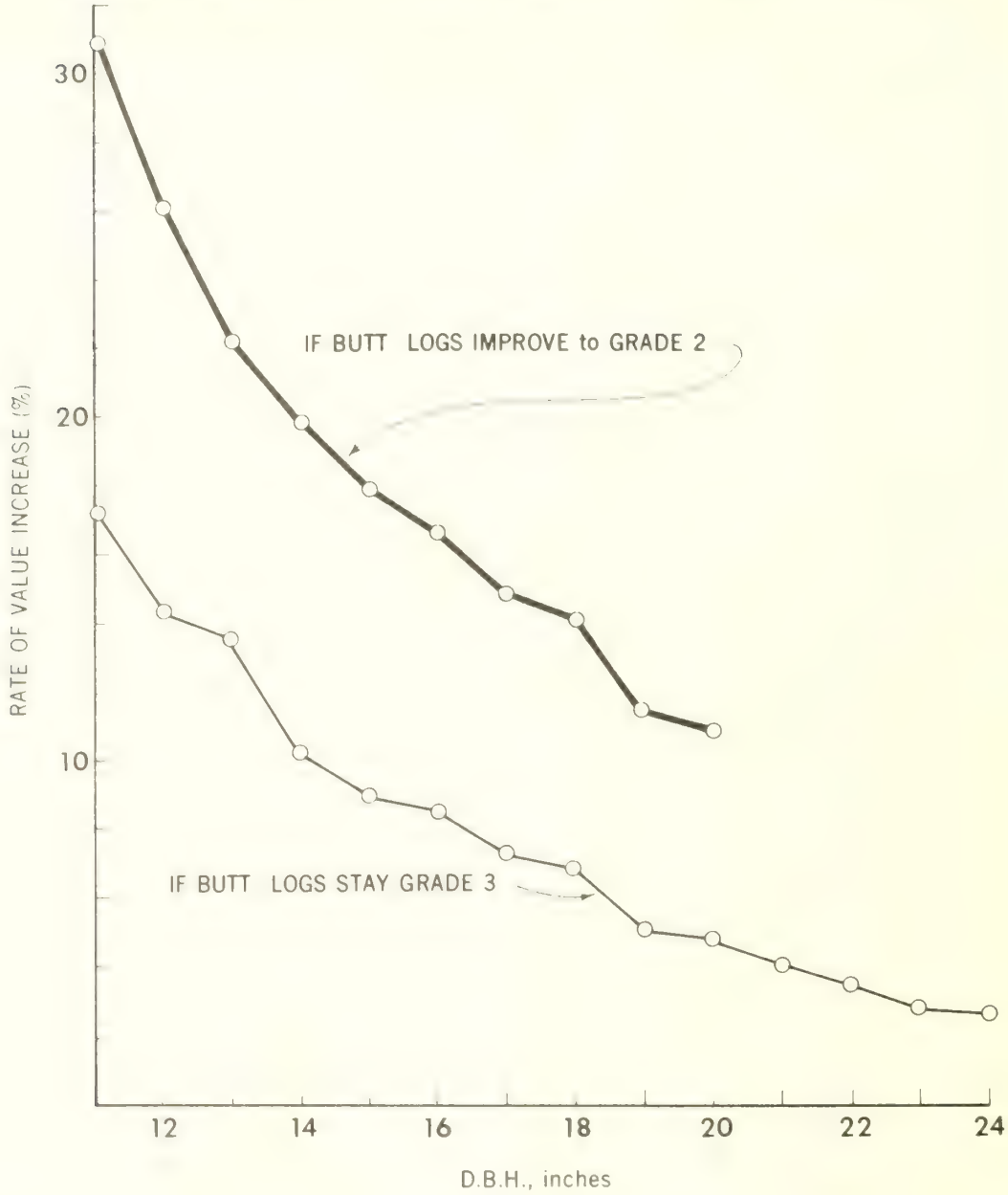
Table 2.—Tree value increases based on growth rates of codominant trees growing on good sites and having the potential to develop the best log grades consistent with their diameters

Original dbh	Maximum butt log grade	Tree value			10-year dbh growth	New dbh	Maximum butt log grade	New tree values[a]			10-year value increase[b]		
		1-log tree	1½-log tree	2-log tree				1-log tree	1½-log tree	2-log tree	1-log tree	1½-log tree	2-log tree
Inches	*Grade*	*Dollars*			*Inches*	*Inches*	*Grade*	*Dollars*			*Percent*		
						YELLOW-POPLAR							
11.0	3	0.21	—	—	2.1	13.1	3	0.81	—	—	286	—	—
12.0	3	.47	.54	—	2.1	14.1	2	3.57	4.45	5.01	660	724	—
13.0	3	.81	1.01	1.06	2.1	15.1	2	4.49	5.65	6.32	454	459	496
14.0	2	3.57	4.45	5.01	2.0	16.0	1	5.97	8.19	9.83	67	84	96
15.0	2	4.49	5.65	6.32	2.0	17.0	1	7.27	10.05	12.36	62	78	96
16.0	1	5.97	8.19	9.83	1.9	17.9	1	8.97	12.28	15.09	50	50	54
17.0	1	7.27	10.05	12.36	1.9	18.9	1	10.83	14.87	18.29	49	48	48
18.0	1	8.97	12.28	15.09	1.8	19.8	1	12.93	17.68	21.78	44	44	44
						RED OAK							
11.0	3	0.32	—	—	2.2	13.2	3	0.87	—	—	172	—	—
12.0	3	.56	.60	—	2.2	14.2	2	2.96	3.79	—	429	532	—
13.0	3	.87	1.01	—	2.2	15.2	2	3.81	4.92	—	338	387	—
14.0	2	2.96	3.79	4.40	2.1	16.1	1	7.74	10.08	11.41	161	166	159
15.0	2	3.81	4.92	5.66	2.1	17.1	1	9.30	12.23	14.24	144	149	152
16.0	1	7.74	10.08	11.41	2.0	18.0	1	11.32	14.80	17.28	46	47	51
17.0	1	9.30	12.23	14.24	1.9	18.9	1	13.52	17.76	20.83	45	45	46
18.0	1	11.32	14.80	17.28	1.8	19.8	1	15.98	20.87	24.68	41	41	43
						SUGAR MAPLE							
11.0	3	0.04	—	—	1.8	12.8	3	0.59	—	—	1375	—	—
12.0	3	.27	—	—	1.8	13.8	2	2.88	3.76	4.47	967	—	—
13.0	3	.59	—	—	1.8	14.8	2	3.79	4.98	5.86	542	—	—
14.0	2	2.88	3.76	4.47	1.7	15.7	1	9.01	11.28	12.17	213	200	172
15.0	2	3.79	4.98	5.86	1.7	16.7	1	10.86	13.76	15.35	187	176	162
16.0	1	9.01	11.28	12.17	1.6	17.6	1	13.25	16.75	18.79	47	48	54
17.0	1	10.86	13.76	15.35	1.6	18.6	1	15.86	20.19	22.83	46	47	49
18.0	1	13.25	16.75	18.79	1.5	19.5	1	18.79	23.94	27.24	42	43	45

[a]Using the values of the nearest 1.0-inch dbh class.

[b]Value increase must be at least 160 percent to earn 10 percent rate of interest, and 80 percent to earn 6 percent rate of interest.

Figure 2.—Rate of value increase for 2-log red oaks with grade 3 butt logs.



three recent publications describing rates of value increase for individual trees (Mendel and Trimble 1969; Trimble and Mendel 1969; and Mendel, Griesez, and Trimble 1973). Present and 10-year tree values were determined (Mendel, DeBald, and Dale 1976).

To further demonstrate the effect of log grade and tree size on the expected rates of value increase, 2-log red oaks were evaluated for trees of butt log grades 3, 2, and 1 and graphed over a range of dbh classes (Figures 2, 3, and 4). These rates do not include the effects of inflation. To convert these real rates to money rates, simply add on an inflation rate.

Note that for all figures, even without a premium for inflation, the trees in our example that improve in butt-log grade will in-

Smith, H. Clay, G. R. Trimble, Jr. and Paul S. DeBald.
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221.42 653 176.1

Keywords: Growth; diameter limit; stand value; tree grade.

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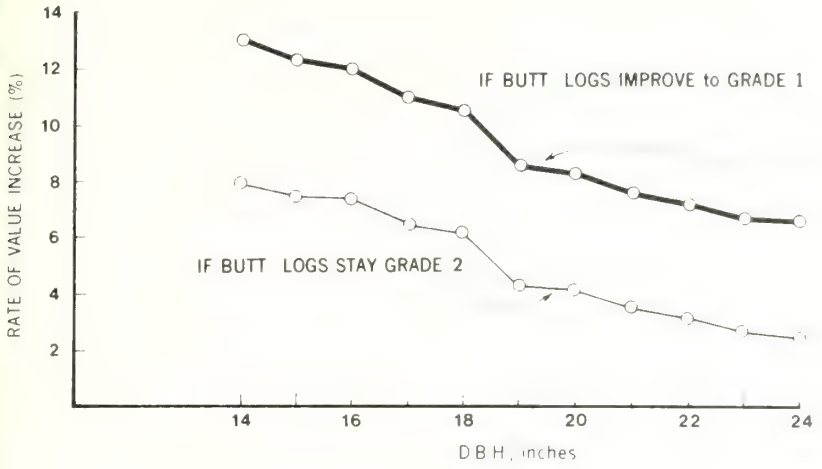
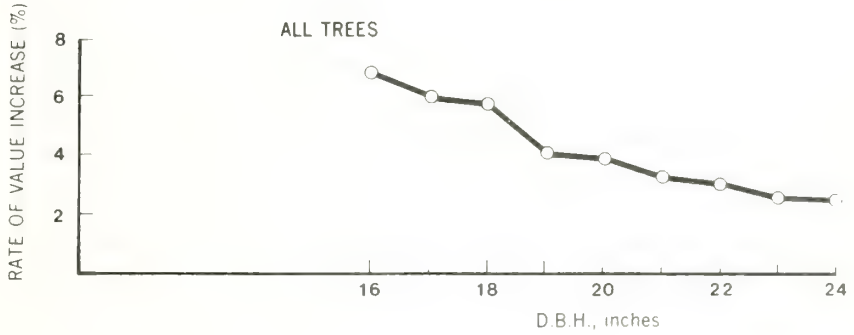


Figure 3.—Rate of value increase for 2-log red oaks with grade 2 butt logs.

Figure 4.—Rate of value increase for 2-log red oaks with grade 1 butt logs.



crease in value at least 6 percent annually. Adding a conservative 4 percent rate for inflation translates the return to a minimum rate of 10 percent.

Note, too, that even those trees that do not improve in butt-log grade exhibit fairly respectable rates through at least part of the diameter range beyond a 14-inch dbh. The degree of fairness and the diameter at which it is no longer a fair return depends, of course, on individual attitudes. Each of us has an alternative interest rate, cost of capital, hurdle rate, or whatever we choose to call it. No one, single rate applies to us all. Thus, we cannot recommend a particular diameter limit to substitute for the 14 inch diameter limit.

The data (in Table 2) indicate without question that tree value is greatly increased by leaving trees that have the potential to develop better butt-log grades through an increase in diameter. Some additional examples of this are:

1) A 1-log, 12-inch dbh red oak, which has about a 15-inch stump diameter (Table 2), can have a butt-log grade of 3. It can have at best a grade 3 butt log worth $0.56 after deducting extraction and milling costs. This tree may not pay its way out of the woods right now. However, if left standing for 10 years and with a butt-log grade increase to 2, the tree value will increase by $2.96 or 429 percent over its present value, an 18-percent annual rate of interest. Can you envision liquidating an investment that would increase this much in 10 years? The answer would be "yes" only if a higher alternative rate of return was available for investment capital.

2) Take the case of a 2-log sugar maple that is now 15.0 inches dbh with a stump diameter of about 18 inches and a butt-log grade of 2—the best possible grade for a tree of this size (Table 2). The value of the tree is $5.86. If we let it grow 10 years, it can have a dbh of about 16.7 inches, a stump diameter of nearly 20 inches, and probably a grade 1 butt log. It will be worth $15.35, an increase in value of 162 percent, or a 10-percent annual rate of interest. This tree returns a big dollar increase as well as a high interest rate.

3) But what about the tree that already has a butt-log grade of 1? The value of this tree may increase in the future for several reasons: (1) Improved butt-log lumber quality within the grade 1 class because of the addition of clear wood (volume) on the bole, (2) increased tree volume, and (3) improvement in grade of upper logs. We can see, however, that the big jump in value comes from an improvement in butt-log grade (Table 2). Take, for example, a 17-inch 2-log yellow-poplar that has a grade 1 butt log now and a tree value of $12.36. In 10 years it will still have a grade 1 butt log, but its tree value will have risen to $18.29, a 48-percent increase or a 4-percent annual rate of return. The rate of increase is much below that of a tree with a butt-log grade increase.

Other dbh, grade and log height combinations are summarized in Table 2. Over a 10-year period we must have about a 160-percent tree value increase to earn a 10-percent rate of return. An 80-percent increase is needed to get a 6-percent interest rate of return.

DISCUSSION

We emphasize that higher diameter limits are often warranted economically. And we point out some rules of thumb for setting higher diameter limits: the financial-maturity diameters listed in *A Procedure for Selection Marking in Hardwoods Combining Silvicultural Considerations with Economic Guidelines* (Trimble et al. 1974). Diameter limits appropriate to individual owners' financial expectations can be selected. The financial maturity diameters (Table 3) can be adapted from real rates of return to monetary rates of return by simply adding an expected inflation-rate percentage to the real rates shown.

In the use of these established relationships between tree value, log grade and size, the individual has wide latitude in setting cutting

Table 3.—Diameters at financial maturity, by 2-inches classes[a]

Species	Real rate of value increase														
	2%			3%			4%			5%			6%		
	S.I.[b]			S.I.			S.I.			S.I.			S.I.		
	80	70	60	80	70	60	80	70	60	80	70	60	80	70	60
Yellow-poplar	26	26	24	24	22	22	20	18	18	20	18	18	18	18	18
Beech	24	22	22	22	20	20	20	18	18	20	18	18	18	18	18
Black cherry	32	30	30	28	26	24	22	20	18	20	20	18	18	18	18
Red maple	32	30	30	28	26	24	22	22	18	20	20	18	18	18	18
White ash	30	28	28	26	24	24	22	20	18	20	20	18	18	18	18
Sugar maple	32	32	30	28	28	24	22	22	18	20	20	18	18	18	18
Red oak	26	26	24	24	24	22	22	22	20	22	20	20	20	18	18
White oak	24	22	20	22	20	20	20	18	18	20	18	18	18	18	18
Chestnut oak	24	24	22	22	22	20	20	18	18	20	18	18	18	18	18
Other long-lived species	26	26	24	24	24	22	20	20	18	20	20	18	18	18	18

[a]Mark trees of these 2 inch dbh classes and larger, unless potential grade improvement can be foreseen in the next 10 years.

[b]Site index.

diameters. He can set them by individual species, but that would include so many different limits that he would have to mark the stand to obtain compliance with them. Or he could make two or three species groups, which would retain much of the simplicity credited to diameter-limit cutting. In any case, harvest cutting aimed at maximizing stumpage returns would require setting diameters for good vigorous trees that are much higher than the 14-inch stump diameter so widely used.

Also, it is important to mention here that at each harvest cut, regardless of the level at which the diameter limit is set, all culls and poor growing stock should be eliminated if stand high-grading is to be prevented.

SUMMARY

Based on tree value change, it is good business to leave the vigorous high-quality trees that have the potential to increase in butt-log grade or even veneer material. For sawlog-size trees this means cutting to at least a minimum dbh of about 16 inches or a minimum stump diameter of about 19 inches. The increase in tree value with size results from changes in butt-log grade and diameter growth as well as increased volume. The relationship is similar for all hardwood species that are sawed for lumber, although there is considerable variations among species in actual tree-value increases. Using diameter-limit cuts with flexible diameters following financial maturity guidelines has potential to improve current diameter-limit cutting practices.

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A COMPARISON of HEIGHT GROWTH and LEAF PARAMETERS of HYBRID POPLAR CUTTINGS GROWN in OZONE-FUMIGATED ATMOSPHERES

by Keith F. Jensen

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Abstract

Hybrid poplar cuttings were fumigated with an ozone dosage of 15 ppm-hours. One treatment was a steady fumigation at 0.2 ppm while the second fumigation fluctuated between 0.1 and 0.3 ppm. No significant differences were found in cutting height, leaf area, leaf width, and leaf dry weight, but significant differences were found in chlorophyll content and carbohydrate content.

THE STUDY

OZONE is a phytotoxic pollutant that often slows the growth rate of woody species (Jensen 1973, Jensen and Dochinger 1974, Jensen and Masters 1975). Associated with reduced growth rates, the fumigated plants often exhibit leaf injury, a chlorosis, fewer leaves, or premature senescence. These observations strongly suggest that leaf development may play an important role in determining the response of plants to air pollutants (Craker and Starbuck 1972, Ting and Dugger 1968, Ting and Mukeryi 1971, Tingey et al. 1973).

Three leaf characteristics that may be important are leaf size, chlorophyll content, and carbohydrate content. Leaf size is important because it has often been correlated with plant growth (Watson 1952). Chlorophyll may be important because of its involvement in photosynthesis, and carbohydrates because without them growth would be impossible. This study compares growth of hybrid poplar cuttings with these three leaf parameters in clean and ozone-polluted air.

MATERIALS AND METHODS

The basal ends of 6-inch cuttings of hybrid poplar clone 207 (*Populus deltoides* Bartr. × *P. trichocarpa* Torr and Gray) were soaked in a solution of 50 ppm IBA overnight. The cuttings were then potted in a 1:1 mixture of sand and soil in 15-cm plastic pots and placed on the greenhouse bench. After the cuttings had broken bud, 45 uniform cuttings were selected and 15 assigned to each of the following treatments: 1) control, 2) 0.2 ppm ozone for 7.5 hours per day (steady fumigation), and 3) 0.1 ppm, 0.3 ppm, 0.2 ppm, 0.3 ppm, and 0.1 ppm ozone each for 1.5 hours per day (fluctuating fumigation). In both ozone treatments, the dosage (time × concentration) was equal. Treatments were applied 5 days a week.

The cuttings were treated in chambers described by Jensen and Bender (1977). The light intensity was 2,500 footcandles and the photoperiod was 16 hours. Temperature was maintained at 25° ± 2°C and the relative humidity was over 60 percent during the treatment period.

After 6 weeks, total height of all cuttings and the length and width of all leaves of five preselected cuttings in each treatment were measured. The leaves used for leaf measurements were counted and divided into three equal groups: top, middle, and bottom. The leaves were removed by groups, the area measured with an electronic area meter, and a 0.5-g sample frozen for chlorophyll determination. The remaining tissue was dried to constant weight. Chlorophyll content was determined according to the AOAC procedure (1960).

The remaining 10 seedlings in each treatment were randomly divided into five pairs and the leaves counted and divided into three groups per seedling as above. The leaves in each pair-group were removed and cut into small sections, and two 0.5-g samples frozen for carbohydrate analysis. It was necessary to combine the leaves from two seedlings to have enough leaf tissue for the two analyses.

Carbohydrate content was measured by refluxing a 0.5-g sample in 50 ml of 80 percent alcohol for 10 minutes. The sample and liquid were then transferred to a Virtis homogenizer and homogenized for 30 seconds. The mixture was next poured into a Soxhlet extraction thimble and the liquid filtered off and stored. The residue in the thimble was extracted with 100 ml of 80 percent ethanol for 30 minutes, 100 ml of 50 percent ethanol two times, each for 30 minutes, and finally with 100 ml of 20 percent ethanol for 45 minutes. The liquid from each extraction was combined with the

liquid from the reflux treatment and evaporated to dryness in a rotary-flash evaporator. The residue from the evaporation was dissolved in 10 percent ethanol and an aliquot was analyzed for reducing sugar with Nelson's reagent (Nelson 1944). A second aliquot sample was digested with invertase and analyzed for sucrose.

Starch content was determined by transferring the residue from the Soxhlet extraction to a boiling flask and refluxed for 1 hour with 0.2N H_2SO_4 (Smith et al. 1964). The extract was neutralized and analyzed for reducing sugar with Nelson's reagent.

All the variables were subjected to an analysis of variance with a completely randomized design.

RESULTS AND DISCUSSION

No significant differences were found in cutting height, leaf area, leaf width, and leaf dry weight (Table 1). These results precluded an attempt to compare leaf size with height growth.

Leaves exposed to the steady fumigation were longer than those in the fluctuating fumigation and in the control. These results suggest that even though the pollutant dosage may be the same, the method by which the dose is applied may influence plant development. Similar observations have been reported by Temple (1972) and must be considered in interpreting the interaction between plants and air pollution.

Chlorophyll content varied with leaf location and treatment (Table 1). The amount of chlorophyll increased basipetally regardless of treatment. The chlorophyll content of the leaves in the fluctuating fumigation was significantly higher than in the other treatments.

The smaller amount of chlorophyll in the top third of the plants is due to new leaves being formed in this zone. As the leaves stop expanding, the chlorophyll content becomes stable and remains uniform in the middle and bottom portions of the cuttings.

The significantly higher chlorophyll content of the cuttings in the fluctuating fumigation associated with slightly but not significantly smaller leaf area may have played a role in the growth of these cuttings. The photosynthesis rate may have been higher with the increased chlorophyll content so that the amount of photosynthate available for growth remained the same.

The distribution of carbohydrates in the leaves is shown in Table 2. The leaves in the fluctuating fumigation had a significantly reduced sugar content and significantly lower starch content. The leaves in all three treat-

Table 1.—Height, leaf size, leaf dry weight, and chlorophyll content of hybrid poplar cuttings fumigated with ozone, by treatment.

Parameter	Control	Steady fumigation	Fluctuating fumigation
Height (mm)	345a	329a	318a
Leaf width (mm)	58a	58a	56a
Leaf length (mm)	90a	104b	88a
Leaf area (cm^2/cutting)	576a	561a	518a
Leaf dry weight (g/cutting)	3.69a	3.77a	3.21a
Chlorophyll (mg/g fresh weight)			
Top	0.590a	0.573a	1.441b
Middle	1.042a	1.039a	2.275b
Bottom	1.298a	1.137a	2.855b
Average	0.977a	0.916a	2.190b

Values followed by the same letter in the same row are not significantly different at the 0.01 probability level, according to Duncan's Multiple Range test.

Jensen, Keith F.
1979. **A comparison of height growth and leaf parameters of hybrid poplar cuttings grown in ozone-fumigated atmospheres.** Northeast. For. Exp. Stn., Broomall, Pa.
3 p. (USDA For. Serv. Res. Pap. NE-446)

Hybrid poplar cuttings were fumigated with an ozone dosage of 15 ppm-hours. One treatment was a steady fumigation at 0.2 ppm while the second fumigation fluctuated between 0.1 and 0.3 ppm. No significant differences were found in cutting height, leaf area, leaf width, and leaf dry weight, but significant differences were found in chlorophyll content and carbohydrate content.

425:1

Keywords: Air pollution, carbohydrates, chlorophyll.

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425:1

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ments had similar levels of sucrose. The leaves in the top third of the cuttings always had the lowest content of carbohydrates whereas the bottom third had the highest reducing sugar and sucrose content. The leaves in the middle section had the highest starch content.

As with the leaf size measurements, no relationships were found between the carbohydrate content and height. The higher concentration of reducing sugars and low concentration of starch in fluctuating fumigation suggest that the carbohydrates are stored or mobilized differently in these cuttings than in the cuttings in the control and steady fumigation treatments. The sugars apparently were not stored in the leaves as starch but accumulated as reducing sugars.

Table 2.—Carbohydrate content of leaves of hybrid poplar cuttings fumigated with ozone, by treatment (mg/g fresh weight)

Cutting section	Reducing sugar	Sucrose	Starch
CONTROL			
Top	17.7	16.5	19.6
Middle	20.6	20.0	44.3
Bottom	28.5	27.4	33.4
Average	22.3a	21.3a	32.4ab
STEADY FUMIGATION			
Top	17.1	17.9	28.8
Middle	20.7	21.4	53.2
Bottom	24.2	25.7	44.8
Average	20.6a	21.7a	42.3b
FLUCTUATING FUMIGATION			
Top	19.9	13.8	12.8
Middle	28.9	23.3	30.6
Bottom	35.9	28.5	26.8
Average	28.2b	21.8a	23.4a

Values followed by the same letter in the same column are not significantly different at the 0.01 probability level, according to Duncan's Multiple Range test.

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OBSERVATIONS on the USE of GYPCHEK

by F. B. Lewis, R. C. Reardon, A. S. Munson,
H. B. Hubbard, Jr., N. F. Schneeberger, and W. B. White

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1979

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Abstract

This paper reports the results of the 1978 aerial test with the gypsy moth NPV product, GYPCHEK. Although a general population collapse was observed, conclusions could be made on the efficacy of three formulations and two aircraft nozzling systems. The molasses formulation was more effective when applied with Beecomist® nozzles, but Pro-tec™ formulations were more effective when applied with Flat Fan® 8006 nozzles.

INTRODUCTION

THE NUCLEOPOLYHEDROSIS VIRUS (NPV) of the gypsy moth, *Lymantria dispar* L., causes a naturally occurring disease which reaches epizootic proportions as gypsy moth population densities increase (Campbell 1963). In laboratory investigations the virus was found to be highly pathogenic to early-instar larvae (Doane 1967; Magnoler 1974). Tests of the relative virulence of purified and nonpurified NPV preparations of the same isolate have produced conflicting results (Magnoler 1974a; Rollinson and Lewis 1973). Also, tests with different geographic isolates of the virus have shown the Hamden (Connecticut, USA) strain to be one of the most virulent tested (Magnoler 1970; Rollinson and Lewis 1973; Vasiljević and Injac 1973).

Preliminary field studies indicated that the gypsy moth NPV applied on the ground (Magnoler 1974a; Rollinson 1965) and from the air (Yendol et al. 1977) is effective in causing larval mortality, protecting foliage, and reducing egg-mass densities. In 1976, a new NPV product called GYPCHEK replaced the product that had been cleaned and concentrated by isopycnic centrifugation in a K-rotor ultracentrifuge.

However, additional efficacy trials with GYPCHEK were necessary. The product was used in new formulations and applied by different systems for greater protection against ultraviolet light and a longer effective life. Recent field experiments with GYPCHEK have been reported (Wollam et al. 1978).

Reported here are the results of trials to determine the relative effectiveness of each of three NPV formulations used with both conventional (flat fan) and motorized spinning cage nozzle systems.

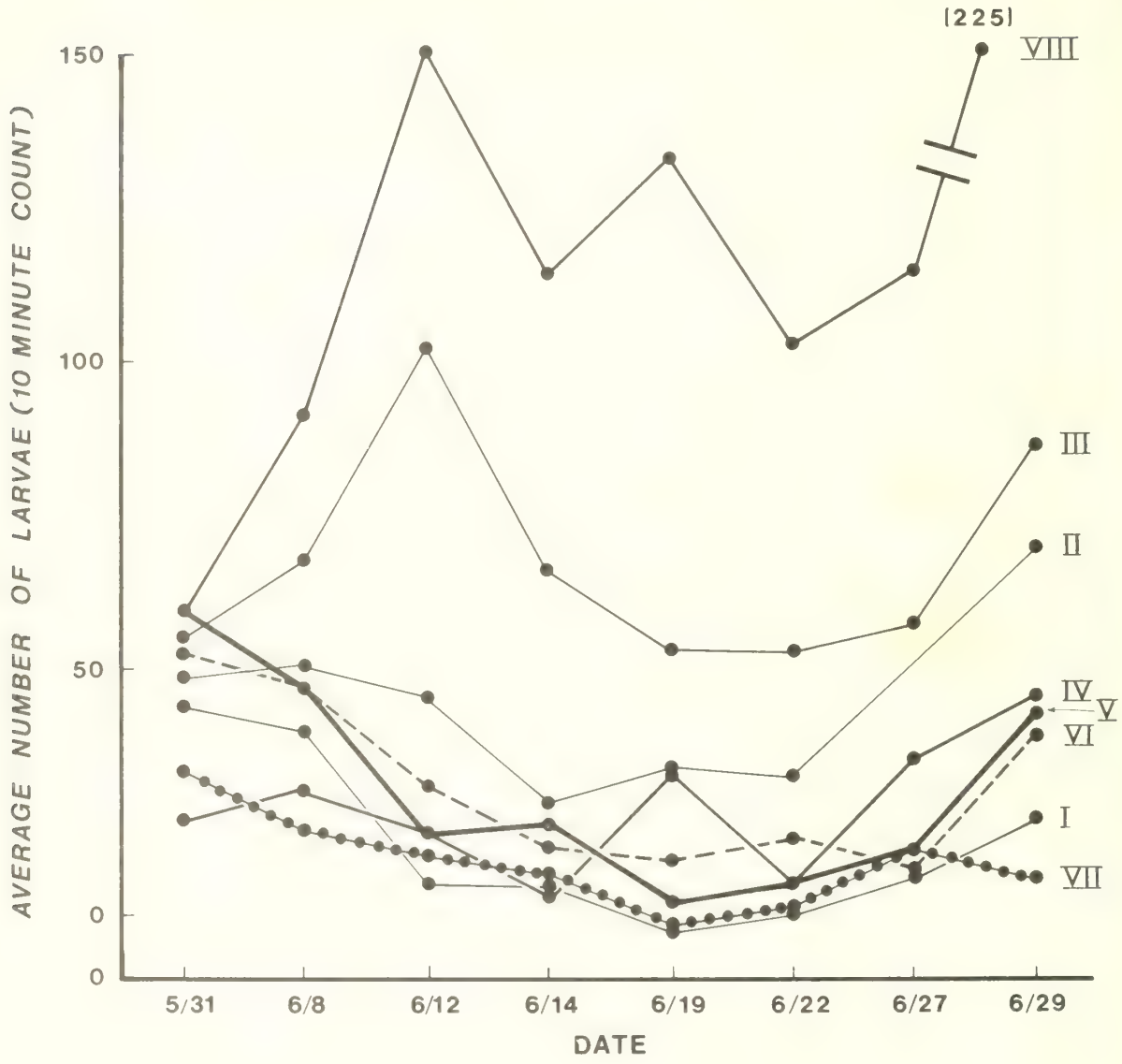
MATERIALS AND METHODS

The gypsy moth-infested experimental area was located in Clinton and Lycoming Counties, Pennsylvania. Twenty treatment plots, 50 acres (20.2 ha) in size, were established. Four additional plots were established as checks. The dominant tree species in the area were oak, *Quercus* spp., 30 to 60 ft (9 to 18.3 m) tall.

Prism points were used as a sampling method to determine spring and fall egg-mass numbers (Wilson and Fontaine 1978). This method was also used for defoliation estimates. In addition, 10-minute larval counts were made twice weekly to estimate large larval densities (Fig. 1). This information was useful in determining the relative effectiveness of the treatments.

A randomized block design and analysis

Figure 1.—Results of 10-minute larval counts taken during the 1978 gypsy moth NPV test.



was used to evaluate three replications each of six treatments, and two replications of a seventh treatment. An initial egg-mass density of between 200 and 1,500 per acre (0.4 ha) was used as the criterion for the block selection.

Virus preparations were applied aerially at the rate of 25 or 50 million Gypsy Moth Potency Units (GMPU) per acre (62 or 120 million GMPU/ha).

Two commercially available adjuvant systems were used with the NPV to evaluate its efficacy in the field. The first two formulations were the "standard"—Shade®[1,2], molasses[3], Chevron Spray Sticker®[4], and GYPCHEK. The third was a polymer-based sunscreen Pro-tec®[5], water and GYPCHEK.

The three tank mixes were:

[1]Mention of a proprietary product is for reference only and does not constitute endorsement by the U.S. Department of Agriculture or the Forest Service.
[2]Sandoz-Wander, Inc., Homestead, Fla.
[3]Pacific Molasses Corp., Baltimore, Md.
[4]Chevron Chemical Co., Perth Amboy, N.J.
[5]United States Trading International, Inc., Washington, D.C.

1.	NPV: 25 or 50 million GMPU	62 or 124 million GMPU
	Shade: 1 lb	1.1 kg
	Molasses: 0.5 gal	4.7 liters
	Chevron: 6 fluid oz	440 ml
	water: to 2 gal	to 18.7 liters
2.	NPV: 25 million GMPU	62 million GMPU
	Shade: 0.5 lb	.56 kg
	Molasses: 0.5 gal	4.7 liters
	Chevron: 6 fluid oz	440 ml
	water: to 2 gal	to 18.7 liters
3.	NPV: 25 million GMPU	62 million GMPU
	Pro-tec: 0.25 gal	2.3 liters
	water: 1.75 gal	16.4 liters

The seven treatments used in this experiment are shown in Table 1.

Two applications of each tank mix were made. The initial application date was determined by two factors: when at least 50 percent of the gypsy moth larvae were in the 2nd instar and when leaf expansion was at least 50 percent for white oak, Q. alba L. The first application was made May 28-29. The second application was made June 4-6 on all blocks. All applications were made in the evening between 4 p.m. and sunset. Three 450-hp Gruman AgCats® were used. All three aircraft had standard spray booms, two were equipped with Beecomist® nozzles with perforated sleeves and the third had 52-8006 Flat Fan® tee-jet nozzles. The swath width was 50 ft (15.2 m), the air speed was 95 mph (153 km/h), and the spray height was 50 to 75 ft (15 to 22 m) from treetops. Wind did not exceed 10 mph (16.1 km/h). It did not rain within 48 hours of application.

Table 1.—Treatment combination used in 1978 gypsy moth test

Treatment Number	Treatment	Number of replicates
I	Tank mix 1: Beecomist nozzles 25 x 10^6 GMPU/0.4 ha	3
II	Tank mix 1: Flat Fan nozzles 25 x 10^6 GMPU/0.4 ha	3
III	Tank mix 3: Beecomist nozzles 25 x 10^6 GMPU/0.4 ha	3
IV	Tank mix 3: Flat Fan nozzles 25 x 10^6 GMPU/0.4 ha	3
V	Tank mix 2: Beecomist nozzles 25 x 10^6 GMPU/0.4 ha 0.5 lb Shade/0.4 ha	3
VI	Tank mix 1: Beecomist nozzles 50 x 10^6 GMPU/0.4 ha (1978 Gypchek product)	3
VII	Tank mix 1: Beecomist nozzles 50 x 10^6 GMPU/0.4 ha (1977 Gypchek product)	2[a]
VIII	No treatment	4

[a]1977 material available for two plots only.

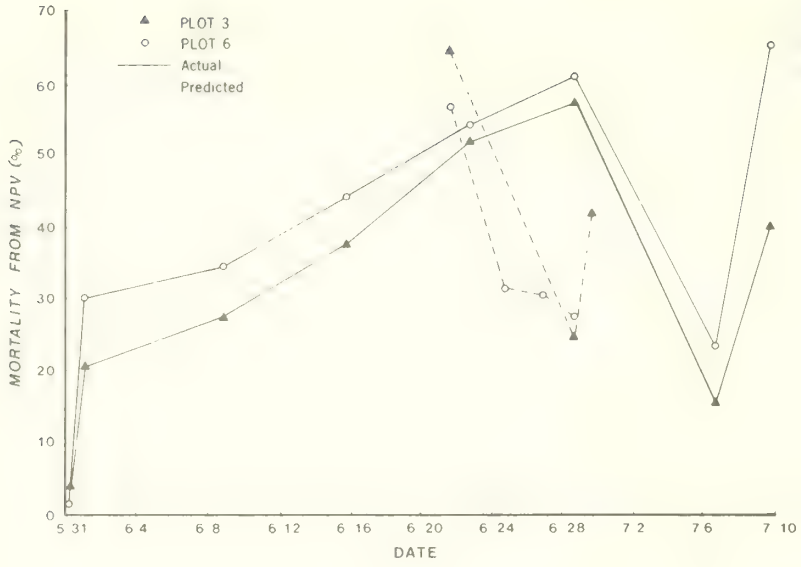
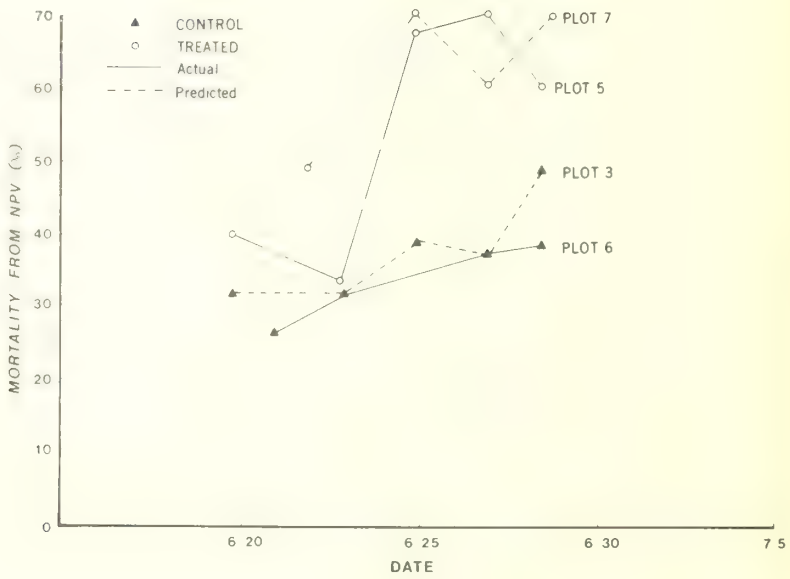


Figure 2.—Actual and predicted mortality from NPV in two control plots.

Figure 3.—Actual and predicted mortality from NPV in treated and untreated plots.



Lewis, F. B., R. C. Reardon, A. S. Munson, H. B. Hubbard, Jr., N. F. Schneeberger, and W. B. White.
1979. **Observations on the use of GYPCHEK.** Northeast. For. Exp. Stn., Broomall, Pa.
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This paper reports the results of the 1978 aerial test with the gypsy moth NPV product, GYPCHEK. The molasses formulation was more effective when applied with Beecomist® nozzles, but Pro-tec® formulations were more effective when applied with Flat Fan® 8006 nozzles.

453--411/414.22

Keywords: Gypsy moth, NPV, aerial spraying, *Lymantria dispar,* microbial control.

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1979. **Weight and volume yields from thinning two oak-hickory stands.** Northeast. For. Exp. Stn., Broomall, Pa.
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Two sample plots in oak-hickory stands of poletimber-small sawtimber were thinned; one was thinned from 111 ft^2 to 53 ft^2 of basal area per acre, and one was thinned from 120 ft^2 to 84 ft^2 of basal area per acre. Products available are classified and described for weight, volume, diameter, length, and species.

525.1:333--014

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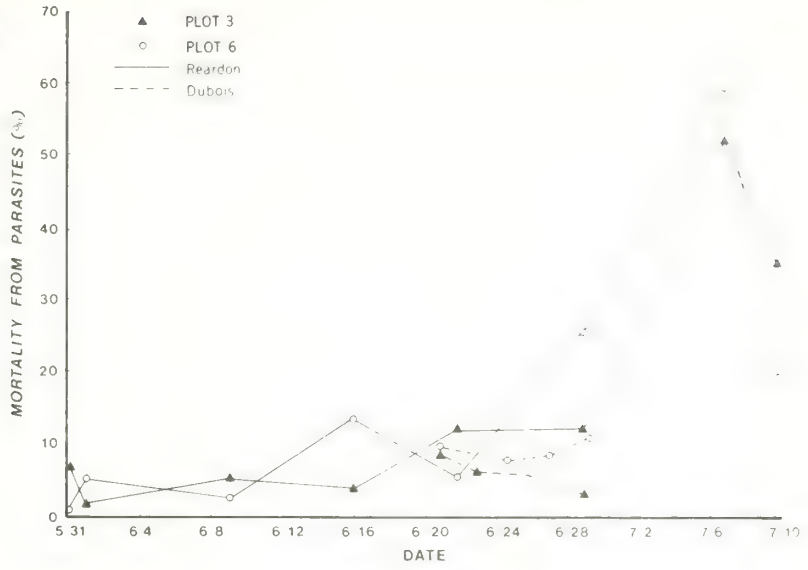
Figure 4.—Actual and predicted mortality from parasites in two control plots.



The number of gypsy moth egg masses was determined by the Wilson and Fontaine method (1978). Preapplication egg-mass densities ranged from 200 to 1,500 per acre (500 to 3,750 EM/ha). Postapplication egg-mass counts were made in September and October 1978. Because the counts were low (less than 100 EM/acre; 250 EM/ha), three 0.1-acre (.04 ha) sampling areas were examined in each plot in addition to the prism points.

Defoliation of oaks at each prism point was estimated and all tree species were determined when larval feeding stopped.

White Kromekote®[6] spray cards were used in selected plots to determine the size of spray droplets and the number of droplets per cm^2. The cards were collected after spraying and stored for evaluation.

Bioassay data were collected to establish the efficiency of the mixing system. Samples were taken to record dispersion of the NPV throughout the mixing and loading operations before and after application. Thoroughness of mixing was determined by sampling the mixing tank before loading the aircraft. Samples also were taken from the loading hose and the aircraft tanks after spraying and temperatures were recorded to determine if potentially inactivating temperatures had been generated by the mechanical mixing action.

Parasite and other natural mortality factors were assessed by collecting 100 larvae weekly from treated and untreated areas and rearing them in a field laboratory. The actual incidence of parasitism and virus mortality was then recorded (Figs. 2-4).

A second collection of larvae was made to test a system being developed (and being reported elsewhere) to predict virus incidence before its natural expression in gypsy moth populations (Figs. 2-3). Also accumulated were data to predict parasite activity (Fig. 4).

[6]Champion Paper and Fiber Co., Hamilton, Ohio.

RESULTS AND DISCUSSION

Mixing efficiency

Eighteen of the 20 spray mixes used in this test were sampled before loading. All 18 were within the calculated potency range (±10 percent). The water used in preparing the spray formulations was tested and had no effect on the potency of the GYPCHEK used. It was concluded from these quality control tests and bioassays that the mixing of the GYPCHEK in the various formulations was adequate and yielded the desired potency before spraying.

Larval counts

Despite a spontaneous reduction in the gypsy moth population during the study, it was possible to assess the effectiveness of each treatment by evaluating 10-minute larval count data for each treatment group (Fig. 1, Table 2). Treatments generally reduced the larval populations by two to ten fold compared with the controls (Group VIII).

Groups I and II were treated with the same tank mix (1), the only difference being that spinning sleeve nozzles were used in Group I plots while flat fan (8006) nozzles were used in Group II. A comparison of the 10-minute counts showed that the larval reduction from the use of spinning nozzles was about twice that from the use of flat fan nozzles.

However the reverse was true for Groups III and IV. Both groups were treated with the same tank mix (3), nozzle type being the only difference. The larval reduction from applications with the flat fan nozzles (Group IV) was more than twice that from applications with spinning nozzles.

These comparisons point up the fact that the formulation and the application system must be compatible to provide the maximum effect of the treatment. Mix 1 was thick and heavy (11 lb/gal) (1.25 kg/.95 liter) whereas Mix 3 was watery and light (8 lb/gal) (0.9 kg/.95 liter). Thus, better results were achieved when Mix 1 was applied with spinning sleeve nozzles. Mix 3 apparently was better when applied with flat fan nozzles.

On the basis of the 10-minute count, there was little differences between Groups I and V. The only difference between the two groups was that the formulation for Group V contained half the concentration of Shade (0.5 lb; .22 kg). This indicates that the concentration of Shade can be reduced without seriously affecting the formulation.

Mixes applied to Groups VI and VII contained twice the amount of GYPCHEK than the other formulations, the only difference being the source of GYPCHEK. On the basis of the 10-minute counts, the use of twice the amount of GYPCHEK, compared with Group I, does not materially affect the efficacy of the formulation.

Defoliation estimates

Because of the population collapse in the general area, no conclusions can be drawn on the basis of defoliation estimates. Total defoliation on all plots treated and untreated, was 10 percent or less. Oak defoliation did not exceed 15 percent in any plot.

Table 2.—Summary data from 1978 gypsy moth NPV test

Plot group	Average no. larvae (10-min count)	Percent defoliation (all spp.)	No. larvae hatched/0.4 ha	Egg-mass counts			
				Prespray	Postspray		
					Prism	.04 ha	Average
I	21.3	7.1	83001	758	6.0	3.3	4.6
II	41.7	10.5	47573	528	8.0	4.3	6.2
III	66.9	7.2	79145	614	3.7	0.0	1.9
IV	27.9	6.0	44296	490	1.7	0.0	0.9
V	29.6	7.2	50809	602	9.0	10.0	9.5
VI	30.8	7.0	21943	335	7.3	3.3	5.3
VII	17.8	7.2	40701	368	3.0	6.5	4.8
VIII	123.4	9.1	50333	478	0.7	5.0	2.9

Even though larval populations were sufficient to cause noticeable defoliation in some plots (Fig. 1), the very small amount of defoliation in these plots indicated that the factors causing population collapse exerted their influence before the larvae reached the size to cause significant defoliation. Figure 2 indicates that no major viral epizootics took place and Figure 4 indicates that parasite activity did not occur soon enough to have a significant effect on reducing the populations and on defoliation at the time when this would have to occur to result in so little final defoliation. Although natural NPV larval mortality was observed in the control plots (Fig. 3) its incidence was considerally less than that observed in the treated plots (Fig. 3). However, the levels of virus activity in the check plots did not seem high enough to be the only cause of the general population collapse. However NPV obviously was the principal cause of the collapse.

Egg-mass change

On the basis of the egg-mass data obtained in this test, it is impossible to conclude that any treatment had an impact on the populations. The final egg-mass counts, whether obtained by the fixed and variable plot technique or the 0.1-acre (.04-ha) sampling technique, represent the total accumulated mortality due to treatment and other effects. It is apparent that treatments had no deleterious effects on other mortality factors, either intrinsic or extrinsic. A comparison of the final egg-mass counts made by each counting system indicates that either system seems suitable. The major discrepancy between the two systems was in estimating the final egg-mass counts in the four check points.

CONCLUSION

The data accumulated in this test do not provide a solid basis for determining the effects of the NPV treatments on gypsy moth populations in central Pennsylvania.

The 10-minute counts and the viral prediction data do indicate that treatment effects in the sprayed plots were quite different from those observed in the control areas at a time when the virus effect should occur.

The data also indicate there was no heavy virus epizootic in the natural populations and that parasite activity, although contributing to the general population collapse, did not occur early enough in the populations to account for the very little defoliation observed in the test area. Although initial feeding populations in the area were relatively low, there were sufficient numbers to result in noticeable defoliation if mortality had not occurred. The exact cause or causes of the population collapse remain unknown.

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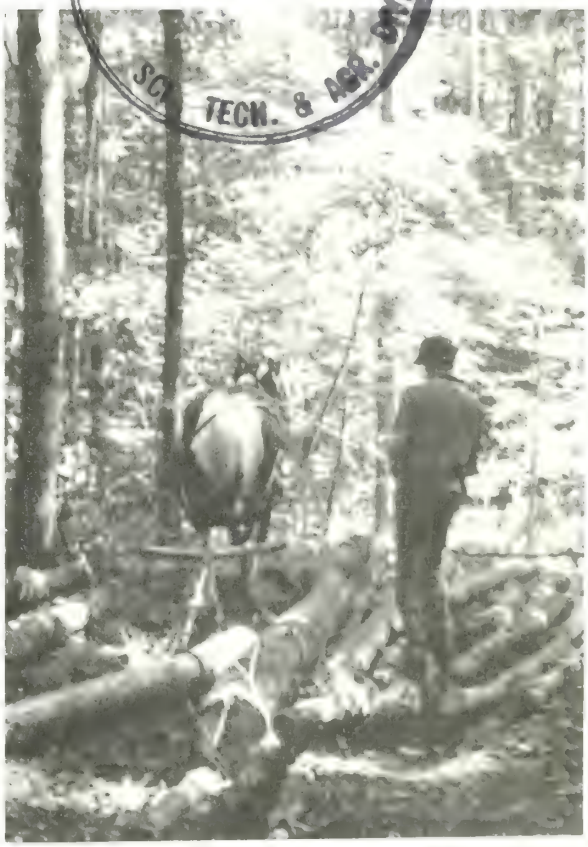

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Abstract

Two sample plots in oak-hickory stands of poletimber-small sawtimber were thinned to determine product yields from thinnings. One stand received a light thinning; the other was heavily thinned. Light thinning reduced basal area from 120 ft^2 to 84 ft^2 per acre and removed 22 tons of roundwood per acre, including 2,543 board feet of sawed products and 7 tons of pulpwood and firewood. Heavy thinning reduced basal area from 111 ft^2 to 53 ft^2 per acre and removed 48 tons of roundwood per acre, including 5,319 board feet of sawed products and 16.9 tons of pulpwood and firewood.

INTRODUCTION

AN ESTIMATED 8 million acres of the oak-hickory forest type in the Northeast need thinning or improvement cutting (U.S. Department of Agriculture 1973). Most of this acreage is in poletimber-small sawtimber stands, and about 85 percent is on farms or other private ownerships. Intermediate cuttings in these stands can increase both total yields and the value of the final harvest by concentrating growth in the more desirable trees. More extensive use of thinning material would encourage intensive management by providing landowners with an immediate source of revenue from intermediate cutting.

New or improved harvesting and processing systems will be required before large-scale commercial thinning in poletimber stands can become a reality. Most existing logging and sawmill systems are designed for larger, higher grade timber; thus small trees cannot generally be used efficiently. The development of improved systems will require more information on the types and quantity of products that can be recovered from thinnings. This report provides weight and volume yields of products from thinning two stands in the oak-hickory types.

STUDY AREA

Two sample plots were established in oak-hickory stands on the Jefferson National Forest, Virginia. The first plot, located in Smyth County near Sugar Grove, contained 10.3 acres; the second plot, located in Giles County near Kire, contained 7.5 acres. Both plots were considered to be representative of several thousand acres of overstocked poletimber-small sawtimber stands on the Jefferson National Forest.

The first plot is in a small cove with slopes averaging 25 percent, average elevation is 3,200 feet, stand age is 50 years, and site index is 75 for upland oaks (Hampf 1965). Initial stocking was 120 ft^2 of basal area per acre including 10 percent saplings, 35 percent poletimber, and 55 percent small sawtimber. Species distribution of basal area included 41 percent red oaks (*Quercus rubra*, *Q. coccinea*, and *Q. velutina*), 24 percent white oaks (*Q. alba* and *Q. prinus*), 12 percent yellow-poplar (*Liriodendron tulipifera*), 10 percent soft maple (*Acer* spp.), 3 percent hickory (*Carya* spp.), and 10 percent other hardwood species (Table 1).

The second plot is on a northern exposure averaging less than 10 percent slope. Stand elevation is 2,600 feet, average stand age is 60 years, and site index is 65 for upland oaks. Initial stocking was 111 ft^2 of basal area per acre, including 7 percent saplings, 51 percent poletimber, and 42 percent small sawtimber. Species distribution of basal area was 59 percent white oaks, 7 percent red oaks, 16 percent yellow-poplar, 4 percent magnolia (*Magnolia* spp.), and 14 percent maple and other hardwoods (Table 1).

The oaks were predominant in both plots (65 percent of basal area for Plot 1 and 66 percent for Plot 2). Red oak constituted 63 percent of all oaks in Plot 1 and 11 percent in Plot 2.

PROCEDURE

National Forest personnel marked both stands for thinning to improve crop-tree spacing and reduce stand density. On Plot 1, the thinning reduced the number of trees from 456 to 251 per acre, reduced basal area from 120 ft^2 to 84 ft^2 per acre, and increased the mean stand dbh (diameter breast height) from 6.9 to 7.9 inches. On Plot 2, the thinning reduced the number of trees from 415 to 103 per acre, reduced basal area from 111 ft^2 to 53 ft^2 per acre, and increased the mean dbh from 7.0 to 9.7 inches.

On Plot 1, all trees designated for thinning that were 5.6 inches dbh and larger were felled, topped at a 4-inch minimum dob (diameter outside bark), and skidded to a central landing. On the average, 50 trees per acre were harvested. One hundred fifty five additional trees per acre were designated for removal, but were less than 5.6 inches dbh. Skidding was done by Forest Service personnel with a 34-hp wheeled tractor equipped with a rear mounted winch (Fig. 1).

Each stem was bucked to yield the longest sawable pieces from 4 to 14 feet long as fol-

Table 1.—Stocking by species for two study plots

Species	Basal area per acre			Trees per acre			Mean dbh		
	Initial stand	Designated cut	Designated residual	Initial stand	Designated cut	Designated residual	Initial stand	Designated cut	Designated residual
	Square feet			*Number*			*Inches*		
PLOT 1									
Red oaks[a]	49	12	37	92	18	74	9.9	11.1	9.6
White oaks[b]	29	11	18	83	43	40	8.0	6.8	9.1
Yellow-poplar	14	2	12	26	2	24	9.9	13.5	9.6
Red maple	12	4	8	53	37	16	6.4	4.4	9.6
Hickory	4	1	3	38	7	31	4.4	5.1	4.2
Others	12	6	6	164	98	66	3.7	3.4	4.1
All species	120	36	84	456	205	251	6.9	5.6	7.9
PLOT 2									
White oaks[b]	65	32	33	184	118	66	8.0	7.1	9.6
Red oaks[a]	8	4	4	14	11	3	10.2	8.2	15.6
Yellow-poplar	18	8	10	44	25	19	8.7	7.7	9.8
Magnolia spp.	5	4	1	36	34	2	5.0	4.6	9.6
Maple spp.	2	1	1	27	22	5	3.7	2.9	6.1
Others	13	9	4	110	102	8	4.6	4.0	9.6
All species	111	58	53	415	312	103	7.0	5.8	9.7

[a]Includes northern red oak, black oak, and scarlet oak.
[b]Includes white oak and chestnut oak.

Figure 1.—Wheeled tractor with rear-mounted winch on standard three-point hitch used for skidding on Plot 1.

lows: *sawlogs*—pieces at least 7.6 inches dib (diameter inside bark) by 8 feet long that would meet the requirements for Factory Grade 3 or better sawlogs (Rast 1973); *sawbolts*—pieces at least 5.6 inches dib by 4 feet long, straight enough to yield at least one sound square edge 4- by 4-inch cant (NHLA 1974); *poles*—pieces at least 8 feet long and from 5.6 to 7.5 inches dib, straight enough to yield at least one sound square edge 4- by 4-inch cant; *pulpwood*—pieces 4 to 6 inches in diameter by 5 feet long, and larger diameter pieces that were not straight or sound enough to yield a sawbolt; *firewood*—pieces too short for pulpwood or sawbolts.

On Plot 2, all trees designated for thinning that were 5.6 inches dbh and larger were felled, topped at a 4-inch minimum dob, and skidded by a private contractor with horses (Fig. 2). One hundred and eighteen trees per acre were harvested. An additional 194 trees per acre were designated for removal, but were below 5.6 inches dbh and were not considered merchantable by the standards of this study. Stems were bucked as described for Plot 1, with these exceptions: (1) Factory Grade 3 logs less than 13 inches dib were bucked into sawbolts; (2) all sawbolts were cut into 4- or 6-foot lengths; and (3) straight, sound sawbolts 7.5 to 12 inches in diameter by 6 feet long were bucked from the white oak and poplar stems for use as furniture dimension bolts.

Residual stocking on Plot 1 was 84 ft^2 basal area. According to the Upland Hardwoods Stocking Guides published by Roach and Gingrich (1968), this is above the minimum level required for full stocking for this stand.

Plot 2 was thinned more heavily than Plot 1. Residual stocking was 53 ft^2 basal area: this is below the level required for full stocking. On each plot, approximately 80 percent of the trees designated for removal were in the overtopped or intermediate crown classes.

Figure 2.—Horse skidding used on Plot 2.

All roundwood products harvested from both plots were weighed and tallied by product types. Cubic volume and board foot volume (International ¼-inch rule) were determined for each sawlog, sawbolt, and pole. All sawable material was cut into cants, boards, or flitches on the laboratory sawmill. Flitches, 3 and 4 inches thick, were cut from the white oak and yellow-poplar furniture dimension bolts.

The green weight of the aboveground portion of each stand component was estimated using whole-tree weight equations developed by Wartluft (1977).

YIELDS

For Plots 1 and 2 combined, 74 percent of the biomass available for removal was harvested in the form of roundwood products. The unharvested material was in trees less than 5.6 inches dbh, and in the tops of harvested trees. This material did not meet current roundwood merchantability standards and could only be harvested and marketed for whole-tree chips or fuelwood.

Biomass

On Plot 1, an estimated 34 tons per acre of whole-tree biomass[1] was available for harvest; this amounted to 27 percent of total initial stand biomass. The 22 tons per acre of roundwood products harvested accounted for 64 percent of the tonnage available for removal (Table 2).

Estimated biomass available for removal from Plot 2 was 56.7 tons per acre, or 49 percent of the initial stand biomass. The roundwood products harvested weighed 48.3 tons per acre, or 85 percent of available biomass. The increased yield from Plot 2 compared with Plot 1 reflects the heavier thinning (Table 2).

[1]Weight of all material above a *6-inch* stump for trees designated for thinning.

Table 2.—Estimated aboveground green weight of individual stand components (tons per acre)

Stand component	Plot 1	Plot 2
Initial stand	125.4	116.4
Residual trees	91.0	59.7
Trees available for removal[a]	34.4	56.7
Products actually removed	22.0	48.3
Remaining available biomass in trees <5.5″ dbh and residue from cut trees	12.4	8.4

[a]All diameters, including trees less than 5.6 inches dbh—not cut.

Roundwood products

The yield of roundwood from Plot 1 averaged 22 tons or 608 ft^3 per acre. Thirty-two percent of this volume was pulpwood and firewood, 40 percent was sawbolts and poles, and 28 percent was sawlogs (Table 3).

The harvest of roundwood from Plot 2 was 48 tons or 1,453 ft^3 per acre. Thirty-four percent of this volume was pulpwood and firewood, 44 percent was sawbolts and poles, and 22 percent was sawlogs (Table 3).

For both plots combined, 61 percent of the log scale volume came from sawbolts and poles. The remaining 39 percent was from sawlogs.

Sawed products

Sawable roundwood from Plot 1 yielded 2,543 board feet per acre of sawed products, including 39 percent pallet parts and cants, 12 percent furniture dimension stock, and 49 percent standard lumber. Total green-product yield averaged 23 percent overrun based on International ¼-inch rule (Table 4).

Sawable roundwood on Plot 2 yielded 5,319 board feet per acre of sawed products, including 41 percent pallet parts, 21 percent furniture dimension stock, and 38 percent standard lumber and cants. Total product yield averaged 18 percent overrun on International ¼-inch rule (Table 4).

DISCUSSION

The large differences in available biomass and roundwood for removal between Plots 1 and 2 can be attributed to the intensity of the thinning on each plot. Fifty merchantable trees per acre were cut on Plot 1 compared with 118 per acre on Plot 2. However, the

Table 3.—Roundwood yields per acre by product

Item	Weight	Volume		Proportion of cubic volume
	Tons	*Board feet*[a]	*Cubic feet*	*Percent*
		PLOT 1		
Firewood	1.3		36.9	6.0
Pulpwood	5.7		157.6	26.0
4′ sawbolts	4.3	537	118.0	19.4
5′-8′ sawbolts	3.5	457	95.6	15.7
Poles	1.0	119	28.0	4.6
Sawlogs	6.2	953	172.2	28.3
Total	22.0	2,066	608.3	100.0
		PLOT 2		
Firewood	1.4		42.5	3.0
Pulpwood	15.5		457.0	31.4
4′ sawbolts	6.9	848	199.2	13.7
6′ sawbolts	13.0	1,768	382.4	26.3
Poles	2.0	281	60.0	4.1
Sawlogs	9.5	1,623	312.1	21.5
Total	48.3	4,520	1,453.2	100.0

[a]International ¼-inch rule.

Table 4.—Sawed product yields per acre by roundwood class

Item	Log scale	Yield	Overrun	Proportion of sawed products
	Board feet[a]	*Board feet*[b]		*Percent*
		PLOT 1		
4′ sawbolts	537	694	29	27
5′-8′ sawbolts	457	608	33	24
Poles and sawlogs	1,072	1,241	16	49
Total	2,066	2,543	23 (avg)	100
		PLOT 2		
4′ sawbolts	848	1,136	33	21
6′ sawbolts	1,768	2,184	24	41
Poles and sawlogs	1,904	1,999	5	38
Total	4,520	5,319	18 (avg)	100

[a]International ¼-inch rule.
[b]Lumber measure.

average weight and volume yield per merchantable tree cut were similar on both plots: total weight of products average 0.44 tons on Plot 1, and 0.41 tons on Plot 2; average cubic volume harvested was 12.2 ft^3 on Plot 1 and 12.3 ft^3 on Plot 2; sawable volume was 41.3 board feet on Plot 1 and 38.3 board feet on Plot 2.

More important than the differences between plots, the results from both plots show that close utilization can significantly increase both the volume and the value of the material obtained from thinnings in oak-hickory stands. Full use of all trees available for removal would have yielded an additional 10.4 tons per acre, a 30 percent increase in the weight of products removed from both plots. This additional wood from small trees and cut tree residues can be used for wood fiber or fuel.

Converting small logs into sawed products would significantly increase the value of thinning material. For example, the current value of pallet bolts is about twice that of pulpwood. On both plots combined, 61 percent of the log-scale volume of sawable material (43 percent of the total cubic volume harvested) was in the form of sawbolts and poles (Table 3). Although this material is physically suitable for production of pallet parts or similar products, it is either too small in diameter or too short to make factory grade sawlogs. Without a sawbolt market, this material must be marketed as pulpwood.

In parts of the Appalachians, deep-mining operations provide substantial markets for roundwood 4.5 inches dob and larger (Timson 1978a, 1978b). For other parts of the eastern hardwood region, the only large-volume market for small roundwood is for pulpwood. The use of fuelwood is increasing rapidly, and will probably increase the opportunities for thinning the more accessible stands. Altogether, these markets cannot absorb the large volumes of wood potentially available from thinnings. An expanded sawbolt market would not only increase the value of thinning material, but create additional markets for thinning material as well.

We cannot accurately assess the types and volumes of products available from thinnings in the oak-hickory forest type, having sampled only two stands. However, these preliminary results indicate that a tremendous amount of both fiber and solid wood products are available from this source. We are continuing research to develop preharvest predictors of product yields from thinnings for the region's major forest types, for a range of sites, age classes, and stocking levels. We are also initiatting studies to help develop efficient methods for harvesting small trees from thinnings.

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AN ECONOMETRIC MODEL OF THE U.S. PALLET MARKET

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Abstract

A need for quantitative information on demand and price has been expressed by the pallet industry. In response to this, an econometric model of the aggregate U.S. pallet market was developed. Demand was found to be affected by real pallet price, industrial and food production levels, and slipsheet prices. Supply was affected by real price, housing starts lagged 1 year, and productivity within the pallet industry. Industrial production activity had the strongest impact on pallet demand, while real price was the most influential supply variable. Consumption and price projections were developed to illustrate the model's use for providing long-term investment and resource planning information.

INTRODUCTION

THE U.S. PALLET INDUSTRY is composed of approximately 1,300 pallet manufacturing firms; about 50 percent employ less than 10 persons and fewer than 5 percent employ more than 50 persons (Bureau of the Census 1954-1977). The industry is a significant consumer of sawed wood products, accounting for 15 percent of total U.S. production and nearly 40 percent of U.S. hardwood production.

About 20 percent of the total movement of domestic products could be handled by pallets, and 5 percent is palletized.[1] Pallet production increased at an annual compound rate of 8 percent between 1960 and 1975 for a total increase of 271 percent, and the growth picture is equally as promising.

As with any competitive industry, the pallet industry needs quantitative market information. For instance, we know that pallet consumption is influenced by production activity, however, we do not have estimates of how much it will increase if industrial production increases. An analysis of a recent survey of National Wooden Pallet and Container Association members by Wallin and Hill[2] identified a specific need for demand and price information. Seventy-nine percent of the survey respondents said some research was needed while 35 percent said much research was needed. Groups most interested in this information were understandably the sawmill operators and pallet distributors.

Estimates of future demand and price levels should be major determinants of capital expansion in the industry. In addition, estimates of demand can be used to determine potential problems of resource supply and when they might occur. A major concern of the industry is the availability of wood resources for pallet manufacture. Will future pallet production exert a serious strain on economically available wood resources? If so, when, and what can be done to avert potential problems? Will the currently used mix of sawed wood resources have to be changed?

The purpose of this study was to develop a method that can be used by the pallet industry to address such questions, and we used econometrics to develop a model of the U.S. pallet market. The specific objectives were: (1) to identify variables that are reliable predictors of pallet supply and demand by developing a demand-supply model; (2) to develop projection equations with which to quantify the relationships between these variables and pallet consumption and price; and (3) to illustrate how the model can be used to project estimates of annual equilibrium pallet consumption and price levels for the United States.

METHODS AND ANALYSIS

An equilibrium model, consisting of a demand and a supply equation and an identity, was developed. Initially it appeared that the relationship might be logarithmic, since preliminary plots of pallet production over time suggested a logarithmic trend. However, similar plots of pallet production versus other explanatory variables did not show a definite logarithmic relationship.

A further check on the functional form of the model was carried out by estimating a linear version and analyzing it for evidence of serial correlation. Evidence of serial correlation would be an indication that the functional form was incorrect. The residual plots showed no apparent patterns or trends. In addition, the Durbin-Watson D statistic was insignificant, thus lending further evidence of no serial correlation. Therefore, the authors felt that there was not a strong case for using a nonlinear model, and a linear model was adopted.

[1]Wallin, Walter B. 1977. Characteristics of the U.S. pallet industry. Unpubl. rep. on file at For. Sci. Lab., Princeton, W. Va. 78 p.

[2]Wallin, W. B., and M. E. Hill. 1978. Report on NWPCA research survey. Unpubl. rep. on file at For. Sci. Lab., Princeton, W. Va. 107 p.

The general form of the model is:

$$\text{Demand} = \alpha_d P + \beta_o + \beta_1 X_{d1} + \ldots + \beta_p X_{dp} + e_d$$

$$\text{Supply} = \alpha_s P + \gamma_o + \gamma_1 X_{s1} + \ldots + \gamma_q X_{sq} + e_s$$

Demand = Supply = Consumption

where:

Consumption =	domestic production
P =	pallet price
$X_{d1} \ldots X_{dp}$ =	demand predictor variables
$X_{s1} \ldots X_{sq}$ =	supply predictor variables
α_d, α_s =	regression coefficients for price
$\beta_1 \ldots \beta_p$ =	regression coefficients for independent demand variables
$\gamma_1 \ldots \gamma_q$ =	regression coefficients for independent supply variables
e_d, e_s =	error term for demand and supply equations, respectively
β_o, γ_o =	intercept term for demand and supply equations, respectively

The equilibrium model accounts for the interaction between demand and supply, and the interdependence of price and consumption levels. The data base was annual observations of each variable over the sample period 1960 to 1975. Observations for 1976 to 1978 were reserved to test the predictive ability of the model. The data sources for pallet price (mill realization) and pallet production were annual reports of the National Wooden Pallet and Container Association, Washington, D.C.; for the industrial and food production index and housing starts, the Bureau of the Census, 1960-1975; for productivity in the pallet industry, the Bureau of the Census, 1954-1977; and for slip-sheet prices, the Fibre Box Association annual report, 1978.

The three-stage least squares (3SLS) procedure was used to estimate the parameters in the demand and supply equations. Three-stage least squares was selected over other simultaneous equation procedures because it reduces computation and because computer algorithms, such as the SYSREG routine in SAS-76 (Barr et al. 1976), are readily accessible and inexpensive to use.

SPECIFICATION OF PALLET MARKET MODEL

Specification of a model includes the identification of major factors affecting demand and supply. Economic theory provided a basic framework that was augmented by discussions with experts in pallet marketing. Specification also includes assumptions about the simultaneity—or lack of—in the market system. We believe that the pallet system is a simultaneous system because pallet price and quantity appear to be determined jointly.

An alternate market structure would be a recursive system, where quantity in period (t) is a function of lagged prices. Evidence from substantial information on market prices available to pallet producers and users indicates that the simultaneous system more nearly approximates the structure of the pallet market.

For purposes of this study, pallets can be considered producer goods as opposed to consumer goods. McKillop (1967) described the demand for such goods as a function of their price, the price of substitutes, and the output of the user. Supply is a function of the price of goods and the costs incurred in the production process.

Our discussions with marketing people in the industry led us to consider two additional factors for the demand relationship: (1) availability of capital as a measure of business' ability to buy pallets; and (2) an automation index to measure the feasibility of the manufacturing industry to implement a unitized handling system. On the supply side, we also included a factor to measure the availability of wood raw materials to the pallet industry.

Next, variables had to be selected that could represent the identified factors. Selected variables had to be measurable, and projections of them had to be available for use in the consumption and price forecasting equations.

Tables 1 and 2 list the major factors assumed to affect pallet demand and supply, initial candidate variables selected to represent these factors, the expected relationships between the variables and supply and demand, and their units of measurement.

Table 1.—Major demand factors, variables, expected relationships between variables and demand, and units for the pallet model. The designations in parenthesis in the variable column represent the same variables in equations 1 through 4

Factor	Variable	Expected relationship	Unit
U.S. industrial and food production activity	An index of the weighted average production of durable and nondurable manufactured goods (Ind. production)	Positive	Index (1967=100)
Automation index in materials handling field	Shipments of electric industrial trucks (Automation index)	Positive	1000 units
Capital availability in U.S. manufacturing industry	Weighted average of profit after taxes of U.S. manufacturing corporations (durables and nondurables) (Capital)	Positive	$ billion 1967
Pallet Price	Mill realization price which equals total dollar volume of sales ÷ total units produced. This was then converted to an index and deflated by the Wholesale Price Index (Pallet price)	Negative	Index (1967=100)
Price of substitute	Weighted average of corrugated and solid fiber value of shipments ÷ volume of shipments. (Slipsheet price)	Positive	Index (1967=100)

Table 2.—Major supply factors, variables, expected relationships, and units for the pallet model. Designations in parenthesis in the variable column represent the same variables in equations 1 through 4

Factor	Variable	Expected relationship	Unit
Production costs	Weighted average price of 3A Common hardwood lumber and Douglas-fir utility grade (Wood)	Negative	Index (1967=100)
	Wage rate in pallet industry (Wages)	Negative	Wages per man-hour $ 1967
	Price of electric power (Power)	Negative	Index (1967=100)
	Productivity in pallet industry (Productivity)	Positive	Value of shipments in $ 1967 per man-hour production worker
Availability of wood raw materials	Housing starts lagged 1 year (Housing starts)	Positive	1000 units
Pallet price	Mill realization price which equals total dollar volume of sales ÷ total units produced. This was then converted to an index and deflated by the Wholesale Price Index (Pallet price)	Positive	Index (1967=100)

ESTIMATED DEMAND AND SUPPLY EQUATIONS

Parameters in the model were estimated by the 3SLS procedure of Zellner and Theil (1962). The information used to judge whether candidate variables should be retained in the final model were: (1) the size of the beta coefficient in relation to its standard error—the coefficient should be greater than its standard error (ordinarily the "t-statistic" is used, however, this statistic, as well as the R^2 statistic, is only asymptotically valid with 3SLS); (2) the significance of the Durbin-Watson D statistic—it was used to test for serial correlation in the residuals; (3) whether the estimated model met identification requirements; and (4) whether the parameters in the model had the expected sign. The sign was considered important in this study because clear economic interpretation of the model was desired. We were willing to sacrifice some explanatory power (reduction in R^2) to accomplish this goal if necessary.

In the process of estimating the demand equation, we experienced some serious multicollinearity problems because some of the variables are related to the general level of activity in the overall economy. The variable for capital and for the automation index were both highly correlated with industrial production with correlation coefficients greater than .9. We felt that industrial production was a more important explanatory variable, hence, we deleted the other two. Deletion was necessary because high multicollinearity could cause difficulty in interpreting the resulting parameters in the demand equation. The remaining variables in Table 1 (industrial production, pallet price, and slipsheet price) were retained in the proposed demand equation. This equation provided clear economic interpretation and had good explanatory power with an R^2 of .94. Each of the retained variables had a beta coefficient at least twice its standard error and had the expected sign.

Slipsheets are an alternative, or substitute, for the conventional wood pallet used in transportation and storage of goods. Economic theory suggests that prices of substitutes be included in a demand equation for a product. In addition, one must decide whether the prices of substitutes and pallet demand, for example, are determined jointly during the same time period. If they are determined jointly, the model must be so specified.

We concluded that slipsheet prices are not determined jointly with pallet demand and can be treated as an independent variable. Slipsheet prices are determined primarily by economic activity in the paperboard industry as suggested by marketing experts with the American Paper Institute. In addition, we felt that pallet price, not slipsheet price, determines the feasibility of substitution. In essence, although slipsheets are substitutes, their price level is determined by forces outside the pallet system.

On the supply side of the model, three of our production cost variables were not significant. The price of wood raw materials used in pallet manufacture (weighted average of 3A Common hardwood lumber and Douglas-fir utility grade lumber) was not significant. There are two reasons suggested for this: (1) the price of lower grade hardwood lumber does not fluctuate nearly as much as that of the higher grades, hence the price series may not be a good explanatory variable; (2) more important, wood raw materials used in pallet manufacture are often a byproduct of the production of lumber for use in higher grade products such as furniture. Therefore, perhaps the availability of wood raw materials, rather than their price, has a stronger impact on the supply of pallets.

We felt that housing starts, lagged 1 year, were a representative measure of the availability of hardwood lumber. Justification for this assumption rests on the frequency of joint production between pallet raw materials (lumber) and materials for the furniture and cabinet industry. Furniture and cabinet production lags housing starts by a period of 6 months to 1 year, hence the rationale for lagging housing starts. Discussions with pallet manufacturers substantiated this assumption. Therefore, we included housing starts, lagged 1 year, as a supply variable in lieu of lumber prices.

Neither the price of electric power nor wage rates in the pallet industry were considered to be statistically significant. We believe that the productivity variable included probably ac-

counts for most of the variation in pallet supply that is due to the changing wage rates. As wage rates increase, this encourages technological improvements needed to keep production costs down. McKillop (1967) offered a similar explanation for nonsignificance of wage rates in other wood products industries.

Electric power costs did not fluctuate much prior to 1973, and perhaps the price series is really not a good explanatory variable over our data base. However, power costs have been increasing at the relatively rapid rate of 15 to 20 percent per year over the past 6 years. This suggests that the cost of power may play a more important role in supply decisions in the future.

The proposed supply equation included pallet price, housing starts, lagged 1 year, and a productivity variable. The productivity variable was weakest in terms of statistical significance, however, it met our retention criteria. The other variables were statistically stronger with beta coefficients twice their standard errors. The proposed equation offers adequate explanatory power with an R^2 of .83, and provides clear economic interpretation.

Serial correlation in the proposed model was not significant, which suggests that the linear model is adequate, and that no major variables were missing.

Proposed model

The proposed model was obtained by the 3SLS estimating procedure (standard error in parentheses):

(1) Demand = −16961 − 2140 Pallet price
(917)
+2845 Ind. production
(520)
+501 Slipsheet price
(189)
D = 2.07 R^2 = .94

(2) Supply = −233047 + 1965 Pallet price
(978)
+6965 Productivity
(5990)
+57.5 Housing starts
(17.7)
D = 1.50 R^2 = .83

PROJECTION EQUATIONS AND ELASTICITIES

The demand and supply equations (1 and 2) were solved simultaneously to yield reduced form equations suitable for projecting pallet consumption and price.

(3) Consumption = −129635 + 1361.5 Ind. production + 239.8 Slipsheet price + 3631.8 Productivity + 30.24 Housing starts

(4) Price = 52.63 + .693 Ind. production + .122 Slipsheet price − 1.696 Productivity − .014 Housing starts

Elasticities for the pallet model

The relative importance of each variable in the pallet model can be determined by its elasticity; that is, the percent change in the dependent variable associated with a 1 percent change in one of the independent variables, with everything else held constant. However, the reader is cautioned that elasticity is only a partial measure of impact because a change in one of the independent variables may affect other variables within and outside the pallet system that could offset or even amplify the resulting impact on the dependent variable.

Two types of elasticities were calculated: Consumption and price elasticities, which measure the impact of a change in an independent variable on the pallet system; and we also calculated the traditional elasticities which measure the impact of a change only on the demand or supply side of the market.

Again, the reader is cautioned that the demand and supply elasticities can be misleading. They do not integrate both sides of the market as do the system elasticities for con-

sumption and price (Patinkin 1965). However, they do provide useful information to the reader interested in analyzing one side of the market. Marketing analysts, for example, are often interested in identifying an independent variable that can be used as a good indicator of demand. Demand elasticities can provide such information as well as information on the sensitivity of demand or supply to pallet price changes. If one is interested in the total impact of the system of a change in an independent variable, then the consumption and price elasticities are appropriate. The elasticities are presented in Tables 3 and 4. The system elasticities are understandably smaller than the demand and supply elasticities.

Table 3.—Consumption and price elasticities for the pallet model. Elasticities are based on average values for each variable over the sample period

Variable	Consumption	Price
Industrial production index	1.19	.722
Housing starts (lagged 1 year)	.42	−.231
Productivity	.31	−.174
Slipsheet price	.22	.134

Table 4.—Demand and supply elasticities for pallet model. Elasticities are based on average values for each variable over the sample period

Equation	Variable	Elasticity
Demand	Pallet price	−1.84
	Industrial production	2.48
	Slipsheet price	.46
Supply	Pallet price	1.69
	Housing starts	.79
	Productivity	.60

The pallet system is most sensitive to industrial production with an elastic (≥ 1) consumption elasticity of 1.19 and an inelastic (≤ 1) price elasticity of .722. The consumption elasticity suggests that if industrial production increased by 1 percent, pallet consumption could increase by 1.4 million units. The pallet system does not seem to be sensitive to any of the other independent variables as suggested by the low elasticities. The negative price elasticities for housing starts (−.231) and productivity (−.174) indicate that increases in these variables will lower real pallet prices, but by less than the increase in these variables.

The demand and supply elasticities listed in Table 6 again indicate the sensitivity of the pallet market to industrial production. The elasticities also suggest that demand and supply are sensitive to changes in real pallet price levels. The low demand elasticity for slipsheet price was expected because we had originally felt that pallet price was the dominating factor.

ILLUSTRATION OF MODEL USE

This section describes a procedure to develop projections for pallet consumption and price, and to validate the model. The assumptions we made can be modified easily to reflect changing market conditions and varying degrees of market knowledge possessed by potential users of the model. In addition, we describe some potential uses of the projections for developing scenarios of future pallet market conditions.

Projections for independent variables

Projections had to be obtained for the independent variables before projections beyond the data base could be made for consumption and price of pallets. It should be emphasized that accurate independent variable projections are critical to the model. We used Marcin's (1977) projections for housing starts, and made our own projections for the other variables.

A scenario of three sets of economic conditions was used to develop the projections: (1) medium level conditions, which assume these variables will continue their recent historical growth rate established over the period 1970 to 1977; (2) high level, which assume future rates of growth will be 15 percent greater than the historical rate; and (3) low level, which

Schuler, Albert T., and Walter B. Wallin.
1979. **An econometric model of the U.S. pallet market.** Northeast. For. Exp. Stn., Broomall, Pa.
11 p., illus. (USDA For. Serv. Res. Pap. NE-449)

A need for quantitative information on demand and price has been expressed by the pallet industry. In response to this, an econometric model of the aggregate U.S. pallet market was developed. Demand was found to be affected by real pallet price, industrial and food production levels, and slipsheet prices. Supply was affected by real price, housing starts lagged 1 year, and productivity within the pallet industry. Industrial production activity had the strongest impact on pallet demand, while real price was the most influential supply variable. Consumption and price projections were developed to illustrate the model's use for providing long-term investment and resource planning information.

721.1

Keywords: Demand, supply, consumption, projections

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assume future growth rates will be 15 percent lower than the corresponding historical rate. Fifteen percent was used because these variables have fluctuated by this amount over their established norms.

Table 5 shows the compound rates of growth assumed for each of the independent variables over the projection period.

Assessment of predictive ability

The projection equations (3 and 4) were evaluated for predictive ability by comparing predicted values (P) with observed values (A) for 1976-1978 (Table 6). We were interested in evaluating three aspects of the model's predictive ability: (1) ability to project the percentage annual change in consumption and price—Theil's (1975) υ-coefficient was used in this assessment; (2) ability to project annual levels of consumption and price—the mean absolute percentage error (MAPE) and mean percentage error (MPE) were used in this assessment; and (3) ability to project changes in trend direction—turning point analysis was used for this purpose.

Table 5.—Assumed compound rates of growth for the independent variables under three sets of economic conditions

Variable	High	Medium	Low
		percent	
Industrial production Index	4.81	4.19	3.56
Actual slipsheet price	7.83	6.81	5.79
Productivity[a]	3.39	2.95	2.51

[a]Productivity is measured in constant dollars (value of product shipment in $ 1967 per man-hour of production worker).

Table 6.—υ-coefficient, mean percentage error (MPE), and mean absolute percentage error (MAPE) for the projection period 1976-1978. Values near zero imply good forecasts

Projection	υ-coefficient[a]	MPE[b]	MAPE[c]
		percent	
Consumption	.42	−14.3	14.3
Price	1.88	39.0	39.0

[a] $$\upsilon = \frac{\sum_{i=I}^{N}\left[\left(\frac{P_i - P_{i-1}}{P_{i-1}}\right) - \left(\frac{A_i - A_{i-1}}{A_{i-1}}\right)\right]^2}{\sum_{i=I}^{N}\left(\frac{A_i - A_{i-1}}{A_{i-1}}\right)^2}^{1/2}$$

[b] $$\text{MPE} = \frac{1}{N}\left[\sum_{i=1}^{N}\frac{P_i - A_i}{A_i}\right] * 100$$

[c] $$\text{MAPE} = \frac{1}{N}\left[\sum_{i=1}^{N}\frac{|P_i - A_i|}{A_i}\right] * 100$$

where:
A = Actual values
P = Predicted values
N = Sample size = 3

Results listed in Table 6 indicate that the pallet model projects consumption levels and percentage changes in these levels more accurately than those for real price. However, the model did not perform well over the test period. Consumption was underestimated by 14 percent, while price was overestimated by a rather large 39 percent. Due to these large forecast errors, we adjusted the projections beyond the test period (1979-1990). One adjustment process is discussed in the next section.

Turning point analysis for consumption was encouraging because there were no actual turning points (changes in trend direction) and the model predicted no turning points. The real price decreased from 1975 to 1976, continued to decrease in 1977, and then increased in 1978. The model missed the first turning point; however, it accurately predicted the second change (price).

Adjustment of projections

The authors were concerned with the large mean absolute percentage errors (MAPE) for both consumption and price over the test projection period. Therefore, we analyzed the residuals for the pallet model over the sample period 1960-1975. This analysis suggests that the model fits the sample data well with forecast errors of 6 and 3 percent, respectively, for consumption and price. We therefore concluded that a significant change had taken place in the pallet market between 1975-1978. Before projecting consumption and price beyond 1978, we felt that this change had to be incorporated into our projections.

Between 1975 and 1978, pallet consumption has been increasing at a compound annual rate of 21 percent, while the rate over the sample period was 8 percent. We felt that this

dramatic increase was largely due to the rapidly escalating energy costs since 1973. Increasing energy costs have forced many manufacturers to look for less costly materials handling systems—such as the pallet system. Another apect of this increased demand is the fact that many of the new users of pallets are purchasing the cheaper, lower quality pallets because of budget limitations. These pallets must be replaced more frequently, thus further increasing demand.

Rapidly increasing energy costs were also affecting our pallet price projections. Pallet price used in the model was real price (actual price deflated by the Wholesale Price Index of all goods). The Wholesale Price Index (WPI) has been increasing much faster than actual pallet prices between 1975 and 1978. This has resulted in a decrease in real pallet prices over the test projection period. This is probably because items in the WPI are more energy dependent than pallet production.

Due to this dramatic change in pallet consumption and real price over the test period, we adjusted our projections for the period 1979 to 1990. The adjustment process is described below (McKillop 1967):

Adjusted forecast$_{(t)}$ =

$$\hat{y}_t \left[\left(\frac{y_1}{3} + \frac{y_2}{3} + \frac{y_3}{3} \right) \Big/ \left(\frac{\hat{y}_1}{3} + \frac{\hat{y}_2}{3} + \frac{\hat{y}_3}{3} \right) \right]$$

where:

$\hat{y}_t$ = unadjusted forecast for year (t)
y_1 = actual value for 1976
y_2 = actual value for 1977
y_3 = actual value for 1978
$\hat{y}_1$ = unadjusted forecast for 1976
$\hat{y}_2$ = unadjusted forecast for 1977
$\hat{y}_3$ = unadjusted forecast for 1978

The projections were adjusted, upward or downward, by the average amount that the actual values for consumption or price differed from the unadjusted projections over the test period. Using this procedure, we attempted to bring the projections in line with the changes that took place over the test period. In essence, we changed the intercept but left the slope unchanged. Although we did not anticipate the need for such an adjustment process during the early development of this example, it gave us an introduction on how to adjust projections if the need arises.

Adjusted projections for consumption and price

In this example, pallet consumption and price are projected to the year 1990 (Figs. 1 and 2). Consumption is projected to increase (1978 base) between 67 percent (low level) and 106 percent (high level). The medium level projection is for an 87 percent increase. The corresponding compound rates of growth are 4.3, 5.3, and 6.2 percent for the low, medium, and high projections. The real price index is projected to increase (1978 base) between 36 percent (low level) and 58 percent (high level). The medium level is projected to increase 46 percent. The compound rates of growth are 2.6, 3.2, and 3.9 percent, respectively.

Pallet consumption grew at a compound rate of 8 percent for the 15 years between 1960 and 1975, but our projections indicate that the growth rate may moderate in the future.

The data on future consumption and price levels provide an interesting basis for analyzing future pallet market developments. Potential users of the model can develop scenarios to describe various market conditions, anticipated technological changes in pallet use, future availability of wood raw materials, etc. These scenarios can be integrated with our projections, or with their independent projections, to evaluate alternative courses of action to avoid gross misallocation of resources.

One such scenario is that future raw materials supply will remain at historical levels and that technology of pallet use will remain the same, where the ratio of expendable pallets to returnable pallets is roughly one to one. Both of these assumptions are simplistic, but they serve to illustrate how the model can be used to analyze circumstances facing the pallet industry.

If the above scenario did in fact materialize, our projections of 500 million pallets by 1990 would approximate the wood raw materials currently economically available to the pallet industry. Of course, the weakness of such a scenario is that the supply of raw materials will not remain constant. Forest survey data

Figure 1.—U.S. pallet consumption projections under three sets of economic conditions. U.S. consumption = domestic production.

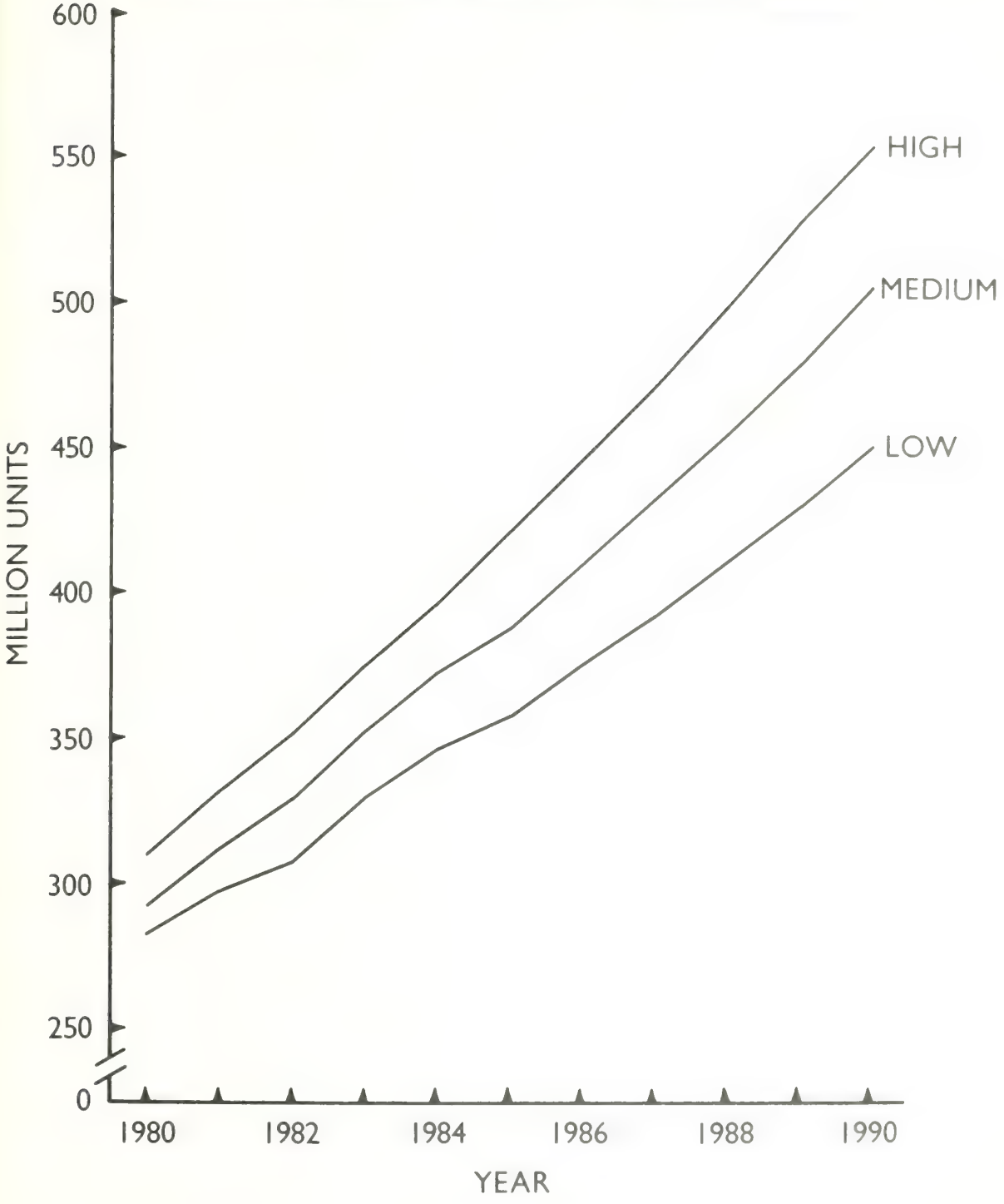
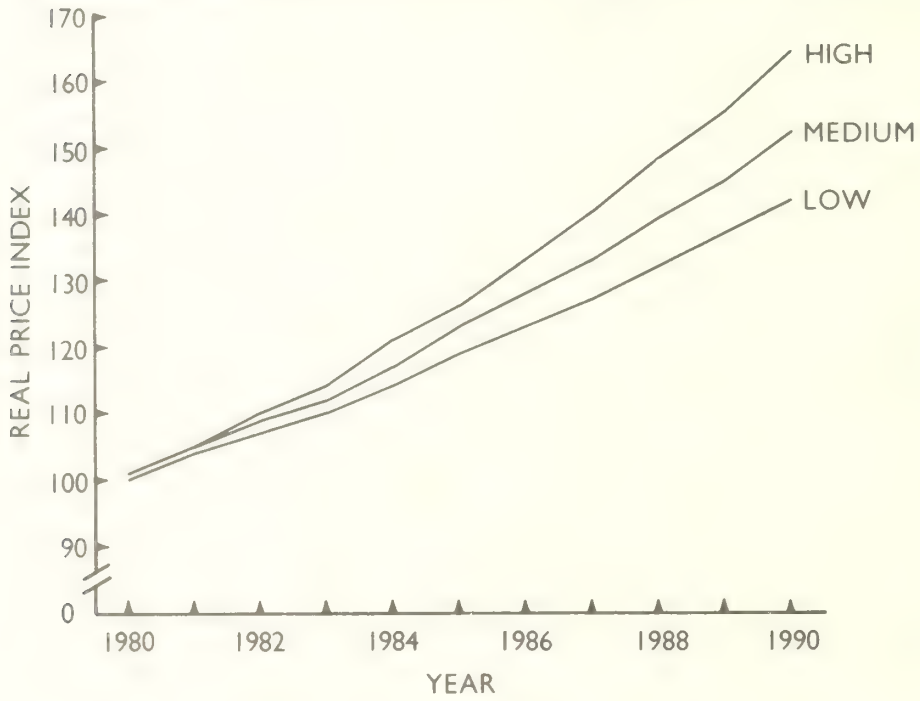


Figure 2.—Domestic real pallet price index projections under three sets of economic conditions. Real pallet price = mill realization price which is equal to total dollar volume of sales ($ 1967) divided by total U.S. production. This was then converted to an index with 1967 = 100.



(U.S. Forest Service 1978) show substantial increases in hardwood volumes as more eastern hardwood stands move from polesize to small sawtimber sizes. The raw materials supply will not remain constant because wood suppliers can be expected to respond to an increased demand for their products.

The other assumption, implicit in this scenario, is that technology of pallet use will remain the same. However, it will not remain the same. Low-quality expendable pallets will give way to returnable pallets; the present designs will give way to more effective designs that use the resource more efficiently. Increasing production costs, particularly those arising from increasing costs of raw materials, are likely to mandate these changes.

The point to be made is that econometric models such as this pallet model can be used by the industry to assess future markets. Such an analysis will provide useful insights into the need for the development of alternative courses of action to effectively deal with changing market conditions. Projections from such models can also provide wood suppliers with useful information on the magnitude of future markets for their products. Such knowledge can be used to profitably guide investment levels in land and other capital resources.

CONCLUSIONS

Projections of pallet consumption and price can be developed from this econometric model in conjunction with alternative scenarios. Elasticities calculated from the model can be used by the industry to monitor changing economic conditions and evaluate their impact on the pallet market. For example, we found that pallet demand is most sensitive to changes in industrial production activity. Industry planners can use such information to detect early warning signs of changing market conditions, and thus help pallet producers operate more efficiently to the mutual benefit of consumers and the industry itself.

The major limitation of the model is its small data base, however it is the best information available at this time.

The validity of the projections beyond the data base will ultimately depend upon: (1) the accuracy of the forecasts of the independent variables; and (2) whether there are any major future structural changes in the industry. A variety of developments could significantly change the estimated relationships among the variables in the demand and supply equations. If changes occur, such as a change in the technology of pallet use, altered conditions will necessitate a new look at any conclusions drawn from the study. There may be a need to reestimate the model and reproject consumption and price periodically.

Need for future studies

The model developed in this study is an aggregate model that is national in scope. However, the pallet market should be segmented according to two criteria: (1) geographic region of resource supply—hardwoods are the major resource east of the Mississippi while softwood lumber is the major resource used in pallet manufacture west of the Mississippi River; and (2) end product market—there are numerous potential markets such as the food pallet market, the construction industry market, the automobile industry market, the U.S. Government market, and the general industrial market. Econometric models that specifically address each of these markets would provide more useful information to pallet producers operating in these markets. The authors are currently addressing this need.

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1978 NATIONAL CAMPING MARKET SURVEY

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by Wilbur F. LaPage
and Gerald L. Cole

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Abstract

This report summarizes the major findings of a 1978 nationwide camping market survey, and compares them with those of similar surveys conducted in 1971 and 1973. It documents recent trends in camping and in the composition of the camping market, and compares camping demand with the available supply of developed campsites. The active camping market in 1978 included 17.5 million households, up from 14.3 million in 1973. However, the number of former campers exceeded the number of active camping households for the first time in 1978. The average growth of the active camping market continues to be about twice that of new households in the United States, though that growth is down sharply from the late 1960's and early 1970's. Currently active campers use about 60 percent of the available campsites.

1978 NATIONAL CAMPING MARKET SURVEY

Foreword

ONE OF THE DIFFICULTIES in meeting the demand of Americans for camping and other forms of outdoor recreation is that data on participation trends have been collected by different survey methods. As a result, planners often have been unable to make sound policy decisions on the basis of comparisons of these trends. By contrast, identical survey methods were used in each of three nationwide surveys of the camping market that have been conducted in this decade. This report is a summary of the most recent survey.

The three surveys were conducted in 1971, 1973, and 1978, by the Opinion Research Corporation, Princeton, N.J., under contract with the USDA Forest Service. Together, they present a changing picture of one of the most important and most complex outdoor recreation markets. For each survey, approximately 2,000 personal interviews were conducted during November and December. Although several questions have been added or deleted between surveys, the questions asked have been nearly identical. Future surveys of the camping market will be conducted at 5-year intervals, the next being in 1983.

Over the years, this research has been supported in part by Cooperative Regional Research Projects NEM-42 and NE-100, and the camping industry.

THE CAMPING MARKET: 1960-1978

Camping population

The camping market is unquestionably our most studied outdoor recreation market. As a result of low-cost, reliable techniques for conducting national sample surveys of the general population, we are considerably more knowledgeable about who camps than where they camp.

The landmark work of the Outdoor Recreation Resources Review Commission (Ferriss et al. 1962) showed there were 3 to 4 million active camping households in the United States in 1960. By 1965, there were about 6 million (Bureau of Outdoor Recreation 1972). In 1971, the first of three in-depth studies of the camping market by the Forest Service identified 12.4 million active camping households (LaPage 1973). The second Forest Service survey 2 years later identified 14.3 million households (Kottke et al. 1975); and the third survey in 1978 identified 17.5 million active camping households (Table 1). Table 2 shows the size of the American camping market in 1971, 1973, and 1978, as a percentage of total households.

From an average annual growth rate of 20 percent in the 1960's, camping declined in the early 1970's to less than 10 percent, and to less than 5 percent in the late 1970's. In terms of the number of people who camp, the growth rate is even lower as the average household declined from 3.33 persons in 1960 to 2.81 in 1978 (Bureau of the Census 1978, 1979).

The annual growth of the inactive camping market (former campers) is almost twice that of the active market. In 1971, one-third of all households contained at least one adult who had camped. By 1978, one-half of the households included an adult who had camped. However, from 1971 to 1978 there was little increase in the percentage of households with currently active campers (19 to 23 percent).

Potential campers

An increase in the number of people who have camped can occur only with a decline in the number of "potential campers;" that is, those in both high and medium potential categories, or those who have thought about camping and would like to try it. Beginning with the 1971 Forest Service study, we have monitored this decline—from 12 percent of all households to 6 percent in 1978. As the high and moderate potential categories feed new households into the active camping market, they absorb replacements from the low and zero potential groups, or those who previously had never considered camping. During the past 5 years, this reserve from the lower potential categories seems to have dried up. And the supply of high potentials is diminishing rapidly due to the growth of the active camping market. The average annual growth of the active market continues to be nearly twice that of new households in the United States (Bureau of the Census 1978) (Table 3).

PARTICIPATION TRENDS

Equipment

Trends in the types of camping equipment in use during the 1970's generally are inconclusive on the basis of the three Forest Service surveys (Table 4) and do not strongly reflect the market for new recreational vehicles during the past decade (Bevins et al. 1979) (Table 5). The incidence of renting or borrowing equipment for the most recent camping trip has declined sharply as more campers have acquired their own. And the incidence of having just bought the equipment has continued to decline since 1971, a possible indication of approaching market saturation (Table 6). Unlike the sales data reflected in Table 5, these purchases include sales of second-hand equipment.

However, among the two classes of inactive

campers (temporarily inactive and permanently inactive), there was little change in the rate of disposal of their camping equipment. In 1973, the majority of inactive campers never owned their own camping equipment and consequently never had to dispose of it. The increase in equipment ownership in 1978 resulted in more equipment disposals by temporarily inactive campers; but one-fourth of the temporarily inactive and one-fifth of the permanently inactive campers still owned their equipment (Table 7). The extent to which this equipment continues to be used by others was not determined.

During the past 5 years, the private sector's share of the camping market has apparently increased while the public's decreased (Table 8). This shift in market shares is probably due to the increased need by campers for utility connections and the higher level of personal service afforded by most private campgrounds.

Experience

The active camping market in 1978 was considerably more experienced than in 1971 when only one-fourth of all active campers had been camping for more than 3 years; by 1978, nearly three-fourths of the currently active campers had more than 3 years of camping experience (Table 9).

Unfortunately, prior to the latest survey (1978), no estimates of actual camping frequency (days per year) were collected. Campers were asked, however, if their participation had been "increasing or decreasing in the past few years." Since 1973, significantly more active campers report an increase in participation (Table 10). All regions and all age groups (head-of-household's age) showed increases, but increasing participation was most common among the 40- to 50-year-olds and in the Northeastern States.

The heavy-half phenomenon, where one-half of all campers are responsible for more than three-fourths of the reported camping days, was noted in 1969 and 1971 (LaPage 1969; LaPage and Ragain 1971), and is again evident in the 1978 national survey data. In 1978, one-half of the active campers accounted for 78 percent of all camping trips and 77 percent of the total reported camping days. And while median participation by active campers in 1978 was only two weekend trips of 3 days each, average participation was 3.4 trips of 4.7 days each (Table 11).

MARKET COMPOSITION

Demographics

Because of the camping market's size and broad appeal to a cross section of society, its characteristics tend to reflect those of the public in general and its trends tend to reflect national trends. For example, in 1973, the income distribution of active, inactive, and potential campers closely paralleled that of all American households in that year. By 1978, the incomes of potential campers and inactive campers continued to reflect the national distribution, while those of active campers revealed a distinct upper income bias (Table 12).

In 1973, the age distribution of all three major camping market classes was strongly skewed in favor of younger heads-of-households. In 1978, the age distribution was more representative for both active and potential campers. The large increase in inactivity among young heads of households in 1978 is probably the result of new people in this age group who formerly camped with their parents and now have households of their own (Table 13).

Occupation, education, sex, home ownership, and size of home town or city all show relatively little change from 1973 to 1978 for the major camping market groups (Table 14). However, three other demographic descriptors (region, marital status, and race) were distinctly different in 1978 (Table 14, 15).

While camping is still predominantly a family activity, there was a distinct increase in single campers and a decrease in married campers between 1973 and 1978 (Table 15). The change is most pronounced among temporarily inactive campers and probably reflects the large increase in temporary inactivity among people 18 to 20 years old (Table 14).

Although the change in the percentage of nonwhites in the active camping market was insignificant during the past 5 years, there is a strong multiracial interest in camping among

both inactive and potential campers (Table 14). In fact, more than one of every four potential campers is nonwhite. This group represents a major opportunity for market expansion that apparently is being ignored or, at best, not effectively pursued.

Regional trends

Gains and losses in the number of campers, by region, are not evenly distributed and do not reflect patterns of population growth for any of the four major regions (Table 1). More than half of the Nation's 3.2 million new campers (from 1973 to 1978) live in the North Central States. Further, the North Central's gains in active campers were accompanied by almost no losses in potential campers or increases in the numbers of temporarily inactive campers. At the same time, the Northeast gained 1 million campers while losing nearly that many to temporarily inactive status. The pattern in the West was similar to the Northeast's, and the Southern States actually experienced a net loss in numbers of campers.

Despite substantial shrinkage in the numbers of potential campers (26 percent), the South continues to have the largest supply of prospective campers. However, if the trend from 1973 to 1978 means anything, that potential does not produce large numbers of active campers in the South. Possibly, by moving from the South, these potential campers later contribute to the active camping market in other regions, particularly the North Central and the West. Similarly, the largest reservoir of temporarily inactive campers is in the Southern States. In 1978, for the first time since the camping market has been studied in detail, the combined total of permanent dropouts and temporarily inactive campers exceeded the size of the active camping market. In the late 1960's and early 1970's there were two active campers for every inactive camper. By 1974, the two groups were about equal in size. Today, the households with former campers outnumber those with actives by more than 2 million.

THE CAMPING EXPERIENCE

Perceptions

Despite enormous changes in the quantity and quality of available camping opportunities and in the nature of the demand for them, the ways in which Americans perceive camping as an outdoor activity seem surprisingly resistant to change. Camping may no longer be "roughing it," but it is more popular today than ever. In assessing the camping market's growth potential, we examined camping's popular image in both the 1973 and 1978 national surveys. Perceptions about camping were determined by the use of a series of word pairs. Each pair of adjectives included a 5-point scale ranging from very favorable to very unfavorable. For example, respondents decide whether camping is pleasant or unpleasant, and to what degree. From the responses emerged a composite image of camping that is substantially more favorable than unfavorable among the general public (Table 16). And there are few significant changes in these images within the major camping market categories over the past 5 years (Tables 17, 18).

Perceptions of camping are particularly important if they act as barriers to participation. For example, if most people who would like to try camping see it as "difficult" or "complex," that perceived "difficulty" becomes a real barrier to participation. In 1973, 50 percent of all prospective campers saw camping as being "easy." By 1978, only 41 percent of the prospective campers held that view of camping (Table 17). Similarly, "comfortable" dropped from 54 to 39 percent for this same group; and "fun" dropped from 57 to 42 percent. Perceptions of "crowding" increased from 35 to 43 percent among potential campers (Table 18).

Among temporarily inactive campers, the same kinds of perceptual barriers reduce the likelihood that they will return to the active market. Perhaps most importantly, increasingly favorable perceptions among active campers could reflect improved conditions and reduced intentions of dropping out of the market. Of the 12 image factors studied, 8 showed higher positive images and 4 had higher negative images in 1978 than in 1973 (Tables 17, 18). For example, active campers in 1978

seemed to feel that camping was less crowded, more convenient, more interesting, easier, and more comfortable than in 1973. However, active campers were less likely to see camping as safe and fun, Table 19 includes image indexes for selected demographic and camping market groups. An image index is the number of persons who have a generally favorable perception of camping for each person who has a generally unfavorable perception.

Satisfaction

Like camping's image, a camper's satisfaction with his last camping trip is remarkably resistant to change (Table 20). Both image and satisfaction are potentially useful indicators for monitoring how well the campground industry is providing quality camping experiences. In view of the rapid growth in the number of inactive campers, our data on images and satisfactions suggest that the accelerated dropout rate apparently is not due to a decline in the quality of camping. The one possible exception is that the availability of utility hookups may not be keeping pace with the demand for more self-contained camping (Table 20).

Also, a minor decline was noted in the 1978 level of satisfaction with camping fees. However, temporarily inactive campers actually were more favorable toward camping fees on their last trip than they were in 1973. The average camping fee ($6.76)[1] apparently has not yet reached the point where it seriously affects participation.

Costs

Camping's "cost image" apparently is changing; camping seems as good a bargain—or better—than it was 5 years ago for all market segments except potential campers (Table 21). Among temporarily inactive campers, the belief that camping is a more economical way of traveling and vacationing was much more prevalent in 1978 than in 1973. The discrepancy in attitudes about camping's cost advantages between potential campers and people who have camped may indicate that an industry-sponsored campaign on comparative costs could stimulate market growth.

Public attitudes about fees also were assessed in 1973 and 1978 by asking people if they believed that camping fees at State and national campgrounds should be high enough to cover all or most of the cost of operating them, or kept low and subsidized by taxes. No significant change in attitude was found among people who have camped; however, there was a strong increase in support of subsidized camping among those who expressed a high interest in becoming a camper (Table 22).

Other activities

The camping experience for most people involves more than temporary living in tents, trailers, or motor homes. Not surprisingly, participation in other major outdoor recreation activities by both active and inactive campers greatly exceeds the average participation rate for these activities (Table 23). Campers participate in boating at twice the national rate. The same is true for hiking, off-road vehicle use, hunting, snow skiing, and canoeing. Participation by campers in selected activities seems a sensitive indicator of general trends in those activities. In monitoring 10 outdoor activities for both the 1973 and 1978 National Camping Market Surveys, it was found that participation trends of campers often paralleled those of the general public.

Camping, like any recreational activity, involves both anticipation (planning) and recollection. To monitor trends in these "off-site" aspects of the activity, we collected information on the frequency of visits to camping and outdoor equipment shows, and on campers and noncampers who have friends and relatives who camp. Both of these measures also provide an indicator of intentions to return to camping by temporarily inactive campers, as well as a means of estimating the intensity of interest in camping by potential campers. Attendance at camping shows was higher for temporarily inactive campers in 1978 than in 1973; but attendance, as well as the incidence of having friends who camp, was down for the potential campers (Table 24). The potential campers of 1978, in many respects, don't seem

[1]News release on campground fees, June 1, 1979, Wheelers Guides, Print Media Services, Park Ridge, Ill.

to have as strong an interest in camping as they had in 1973.

A question added to the 1978 survey was intended to monitor the extent to which camping plans are altered by factors such as energy availability and cost. Preliminary findings suggest that upwards of one-third of the active campers cancelled or shortened trips in 1978 (Table 25). The reasons given most often were "family or personal," "weather," and "lack of time." Cost did not seem a significant factor in 1978, nor was the availability of gasoline. The fact that only 8 percent of the permanently inactive campers had plans to camp in 1978 tends to support the classification scheme that identified them as market dropouts.

SUPPLY AND DEMAND COMPARISONS

Assumptions

Any attempt to relate the camping participation data from this survey to the available supply of campsites in the Nation necessitates accepting a number of assumptions. For example, many of the available camping spaces in this country are used by citizens of Canada and other nations not included in the survey. We have assumed that an equal amount of the camping reported to us by Americans is done outside of the United States. This may be a dangerous assumption if the United States is a net importer of campers, but we have no basis to adjust the assumption at this time.

An equally difficult problem is that of assessing how many of the total estimated camper days are spent at developed campsites as opposed to wilderness, roadside, and open-field camping. Further difficulty arises with the realization that a great many campers doubleup, or camp with another party, on one site. We have assumed that camping with another party on one site is characteristic of at least 5 percent of the camping days.[2] Camping on undeveloped sites has no impact on the supply of available developed sites, so some adjustment must be made for this as well. Since most developed sites, public and private, have an associated fee we have reduced by 20 percent the total estimated camping participation to account for those campers who do not pay fees (Table 20).

Using the total of 17.5 million households that contain people who camped in 1978, this combined reduction (25 percent) results in a total of 13.1 million households that have campers who apparently use the available supply of developed campsites.

Campsite occupancy

One-half of the households (6.55 million) included campers who reportedly camped less than the median of 6 days. The average participation for this group appears to be about two weekends or 4 days. Their impact on the available supply is, therefore, 26.2 million occupied site-days. Campers from the other half of the market camp an average of about 20 days, producing a total of 131 million occupied site-days.

To assess the impact of the total of 157 million occupied site-days on the available supply of campsites (percent occupancy), we need a reliable estimate of that supply. Most major campground directories list just over 1 million campsites. However, directories tend to list only those campsites that meet the publisher's minimum standards. The only available total is provided by the 1974 National Association's of Conservation Districts' 1974 inventory of recreation sites (NACD 1977). According to that inventory, there are an estimated 1,724,712 campsites nationally, but that figure does not include sites in the State of Texas. Woodall's 1978 campground statistics (Woodall Publishing Co. 1978) includes an estimate of 48,114 campsites in Texas. Therefore, our best estimate is 1.77 million campsites in the United States. Of these sites, an estimated one-tenth are open year round, providing 65 million available site-days; the others are open on an average, 120 days each year, providing another 191 million available site-days. By dividing the total occupied site-days (157 million) by total capacity (256 million site-days) we arrive at an occupancy rate of 61 percent.

By way of an independent comparison, in

[2]Unpublished data from a long-term study of campground use in New Hampshire, on file at the Northeastern Forest Experiment Station, Durham, N.H.

1978, a small-scale national survey of occupancy by the National Campground Owners Association revealed an occupancy rate of 58 percent.[3]

CONCLUSIONS

The 1978 National Camping Market Survey documents a turning point in the market. For the first time the number of inactive campers exceeds the actives. People from 27 percent of all households have tried camping and dropped it, temporarily or permanently! And the potential camping market has been reduced to half its size at the turn of the decade. Not only are potential campers fewer in number, they have decidedly less "potential" in terms of their images of camping, attendance at camping equipment shows, and number of friends who camp.

The major implication of this turning point is that the industry must look in new directions for continued market growth. Over the past two decades, that growth has resulted from attracting new (potential) campers. Much of that reserve has now dried up; and what remains includes those who apparently are more resistant to conventional marketing techniques.

The best prospects for sustained growth at this time seem to be in two distinct areas: (1) the 9 million temporarily inactive camping households; and (2) the "light half" of the active camping market—people from another 8 million households who camp less than 6 days each year. The greatest improvement in favorable images toward camping between 1973 and 1978 occurred among: Northeastern adults, heads-of-households in the $10,000 to $15,000 annual income range, and people 30 to 50 years old.

The camping market is clearly changing despite its enormous size and broad appeal. Comparisons with the 1971 and 1973 surveys indicate a number of areas that—if present trends continue—might provide useful marketing clues. The North Central States seem to be the best ones for encouraging new campers to enter the market. Younger heads-of-households (particularly former campers), nonwhites (particularly potential campers), and nonmarrieds clearly have favorable attitudes toward camping and have historically been underrepresented in the market.

Finally, the 1978 survey contains no hint of how the market may react to the worsening energy situation in the United States. Continuation of all of the trends identified in this report is totally dependent on the availability and price of gasoline. It is a fact of American geography that there are few camping opportunities near major urban areas. It seems likely that a continuing energy scarcity could result in a minor campground construction boom near urban areas, despite the apparent adequate numbers of currently available campsites. And the current trend toward a greater proportion of available campsites being rented on a season-long basis probably will be accelerated.

[3]LaPage, W. F., and M. I. Bevins 1978. The nationwide camping indicators program—1978. Report to the board of directors of the National Campground Owners Association.

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APPENDIX

Sampling Procedures

The essential characteristic of probability sampling is that, for each person in the population under study, the probability that he will be included in the sample can be specified. This means that the degree of reliability of any finding from a study based on a probability sample can be estimated mathematically.

Opinion Research Corporation's master sample design is a major improvement over standard area probability designs now in common use. The sampling method eliminates the important problems of traditional probability sampling by using current address directories as the basis of a system for defining interviewing starting points—a system that includes in the sample those households which are not in the directory. The method is both statistically and administratively as efficient as possible, providing the most reliable data for any given expenditure.

The master sample consists of 360 counties in the contiguous United States, six subsamples of 60 counties each. Each of these subsamples is itself a national probability sample.

To construct the sample, all 3,070 counties in the United States were grouped into areas designated by the U.S. Office of Business Economics. These 171 area groupings were then arranged in geographical order from north and east to south and west. Within these geographical orders, counties were arranged by descending population. Three hundred sixty counties were then chosen at random by systematic sampling to fit the above criteria.

The next step was to select an area from each of the 360 counties in the master sample. Again, a probability sampling method was used to select, within each county, a minor civil division (MCD) as defined by the Bureau of the Census. A minor civil division may be a town, township, city, or part of a city. The probability that any particular minor civil division was selected in a county was proportional to the population of that minor civil division. The minor civil division, then, is the primary sampling unit.

The next step is the determining those households where interviewing is to take place. Because they are the most up-to-date and the most complete listing of addresses available, telephone books are the sources of locations adjacent to interviewing starting points when

general public surveys are being done. From this list of households one or more addresses is chosen at random. Each address defines the place that the interviewer begins following the interview site selection process. An interview in a cluster or "neighborhood" does not begin at the household selected from the list, but at the adjacent household, which may or may not be on the original list. Thus, the list does not define the universe of households in an MCD, but rather the list of households adjacent to possible starting points. Depending on the number of households contacted from each starting point, the number of starting points chosen, and the criteria for being included on the original list, every household in the MCD has a known, or knowable, probability of being included in the sample.

The specific persons to be interviewed are selected as follows:

(1) A certain number of starting points are selected from the telephone books covering the minor civil divisions, or communities, selected. The starting points are chosen in a manner that each household, within the minor civil division, listed in the phone book has an equal chance of being selected.

(2) Each starting point selected determines a group of households, called a "cluster," in which interviews are conducted. This cluster of households includes households both with and without listed telephones. The first household in which an interview is conducted is the household immediately to the left of the household selected from the telephone book as the starting point. Thus, the first household can be one either with or without a telephone.

(3) The interviewer conducts an interview in the first household and then (following a prescribed rule) works through the group of households. For example, interviews might be conducted in every third household. The interviewer continues working through the cluster until interviews have been completed in a preassigned number of households.

(4) A respondent-selection procedure determines which person to interview in any given household. Every eligible respondent in the household has the same chance to be interviewed as any other eligible respondent. The interviewer is not allowed to make any substitutions.

Once all interviews have been completed, weighting procedures are employed to ensure that the sample properly represents the population from which it was drawn.

Statistical Interpretation

Reliability of survey percentages

Results of any sample are subject to sampling variation. The magnitude of the variation is measurable and is affected by the number of interviews and the level of the percentages expressing the results.

The table below shows the possible sample variation that applies to percentage results reported from the Opinion Research Corporation sample. The chances are 95 in 100 that a survey result does not vary, plus or minus, by more than the indicated number of percentage points from the result that would be obtained if interviews had been conducted with all persons in the universe represented by the sample.

Size of sample on which survey result is based	Approximate sampling tolerances applicable to percentages at or near these levels		
	10 or 90	30 or 70	50
	Percent		
2,000 interviews	2	3	3
1,000 interviews	2	4	4
500 interviews	3	5	5
250 interviews	5	7	8
100 interviews	7	11	12

Sampling tolerances when comparing two samples

Tolerances are also involved in comparing results from different parts of any one sample and in comparing results between two different samples. A difference, in other words, must be of at least a certan size to be considered statistically significant. The table below is a guide to the sampling tolerances applicable to such comparisons.

Size of samples compared	Differences required for significance at or near these percentage levels[a]		
	10 or 90	30 or 70	50
	Percent		
2,000 and 2,000	2	4	4
2,000 and 1,000	3	4	5
1,000 and 1,000	3	5	6
1,000 and 500	4	6	7
500 and 500	5	7	8
500 and 200	6	9	10
200 and 200	7	11	12
200 and 100	9	14	15
100 and 100	10	16	17

[a]Based on 95 chances in 100.

Sample characteristics, November 1978, Caravan

The data in the table below compare the characteristics of weighted[a] Caravan sample with those of the total population, 18 years of age or over. The table shows that the distribution of the total sample parallels that of the population under study.

Item	Total	
	Population[b]	Caravan sample
	Percent	
Age		
18 - 29 years	30	30
30 - 39	18	18
40 - 49	15	14
50 - 59	15	15
60 years and over	22	23
Race		
White	88	88
Nonwhite	12	12
Metro size		
Nonmetro	32	32
Metro	68	68
Geographic region		
Northeast	23	23
North Central	27	27
South	32	32
West	18	18

[a]Weights were introduced into the tabulations to ensure proper representation of the interviews in the sample.

[b]Source: 1979 data from the U.S. Bureau of the Census, regular and interim reports.

ASK EVERYONE

SECTION C

Col. 5

The following set of questions concerns your interest in family camping and your experience with any of the types of equipment shown on this card.

SHOW EXHIBIT C-1

C1. Within the past two years, have you visited a camping show or recreational vehicle show where any of these types of equipment were displayed?

1 YES
2 NO
3 DON'T KNOW

6

C2. Do any of your friends own or use any of the types on this card?

1 YES
2 NO
3 DON'T KNOW

7

C3. Considering the total cost of camping, including taxes on equipment, campsite fees, extra tolls and insurance, and equipment costs, do you feel that camping is more economical or less economical or about the same as other ways of traveling and taking a vacation?

1 MORE ECONOMICAL
2 LESS ECONOMICAL
3 ABOUT THE SAME
4 DON'T KNOW

8

SHOW EXHIBIT C-4

C4. This exhibit contains descriptive words that can be used to describe camping. As I read the letter before the descriptive word, please choose a point on the scale which is closest to how it would describe your impression of camping.

For instance, if you will look above the list of words, there is an example. If you were describing the weather and you felt it was "a cold day," you would place it on the scale toward #5.

The colder it was, the closer to #5 you would place it. On the other hand, if you felt it was a hot day, you would place it on the scale toward #1. The hotter you thought it was, the closer you would place it to #1. If you felt it was neither very cold nor very hot, you would place it toward the middle of the line.

First, let's start with Description A. What point on the scale is closest to how Description A best describes camping to you. (INTERVIEWER: CIRCLE # FOR DESCRIPTION A AND REPEAT FOR EACH DESCRIPTION.)

						No Answer	
A	1	2	3	4	5	0	9
B	1	2	3	4	5	0	10
C	1	2	3	4	5	0	11
D	1	2	3	4	5	0	12
E	1	2	3	4	5	0	13
F	1	2	3	4	5	0	14
G	1	2	3	4	5	0	15
H	1	2	3	4	5	0	16
I	1	2	3	4	5	0	17
J	1	2	3	4	5	0	18
K	1	2	3	4	5	0	19
L	1	2	3	4	5	0	20
M	1	2	3	4	5	0	21

SHOW EXHIBIT C-1 AGAIN

C5. Have you ever gone on an overnight trip with your family, or with friends, and used any of the types of equipment shown on this card? Do not include any camping trips you may have taken with scouting groups or military experience.

1 YES → SKIP TO Q. C9
2 NO
3 DON'T KNOW

22

(IF "NO" OR "DON'T KNOW" ON Q. C5, ASK):

C6. Have you, as a household, considered such a camping trip in the past 1 - 3 years?

1 YES
2 NO
3 DON'T KNOW → SKIP TO Q. C8

23

(IF "YES" ON Q. C6, SHOW EXHIBIT C-7 AND ASK):

C7. Did you decide not to camp at that time for any of these reasons? Just read me the numbers that apply, please. (Check as many as apply.)

1 2 3 4 5 6 OTHER (Specify): _____
7 NONE OF THESE
8 NO OPINION

24

SHOW EXHIBIT C-8

C8. Which of the statements on this card best describes your household's present attitude toward camping? Just read me the number, please.

1 NEXT YEAR
2 HOPE TO GO IN FUTURE
3 UNLIKELY TO GO
4 NOT INTERESTED
5 DON'T KNOW → SKIP TO Q. C22

25

(INTERVIEWER. CHECK BACK TO Q. C5. IF "YES" ON Q. C5, ASK Q. C9; OTHERWISE SKIP TO Q. C22):

C9 In what year did you last go camping? (Check one)

1 1978 → SKIP TO Q. C12
2 1977
3 1976
4 1975 OR EARLIER

25

(IF "1977 OR EARLIER" ON Q. C9, ASK):

C10 Can you recall why you stopped camping? (PROBE. What specifically has kept you from going camping again since that last trip?)

27
28
29

X HAVE NOT STOPPED → SKIP TO Q. C12

C11. Have you sold your tent, trailer, or other camping shelter, have you given it away, or do you still have it?

1 SOLD IT (or is selling it)
2 GIVEN AWAY
3 STILL HAVE IT
4 DID NOT OWN (rented or borrowed)
5 DON'T KNOW

30

C12. In what year did you first go camping as an adult?

1 1978 → SKIP TO Q. C14
2 1977
3 1976
4 1975
5 BEFORE 1975
6 DON'T RECALL

31

(IF "1977 OR EARLIER" ON Q. C12, ASK):

C13. Has your participation in camping been increasing or decreasing in the past few years? (Check one)

1 ABOUT THE SAME
2 INCREASED LATELY
3 DECREASED LATELY
4 DON'T KNOW

32

C14a. During the past year, did you cancel any of your camping trips, cut them shorter than you planned, or postpone the purchase of a major item of camping equipment? Which of these happened? (Check as many as apply.)

1 TRIP CANCELLATIONS
2 SHORTENED TRIPS
3 POSTPONE PURCHASES
4 NONE OF THE ABOVE

33

(IF "1," "2," OR "3" CIRCLED ON Q. C14a, SHOW EXHIBIT C-14B AND ASK):

C14b. Did this happen for any of these reasons? Just read me the number(s) that apply.

1 2 3 4 5 6 OTHER (Specify): _____
7 NONE OF THESE
8 NO OPINION

34

SHOW EXHIBIT C-1 AGAIN

C15 On your last camping trip, which of these types of camping equipment did you use? Just read me the number, please. (INTERVIEWER: CIRCLE APPROPRIATE NUMBERS BELOW AND ASK Q. C16 FOR EACH TYPE USED IN Q. C15)

35- 1. TENT

C16a For this trip did you
1 Rent
2 Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
36

2. CAMPING TRAILER (Folding)

C16b. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
37

3. TRAVEL TRAILER (Any kind, any size)

C16c. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
38

4. TRUCK CAMPER

C16d. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
39

5. PICK-UP COVER

C16e. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
40

6. MOTOR HOME

C16f. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
41

7. VAN OR BUS CONVERSION

C16g. For this trip did you
1. Rent
2. Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
42

X. OTHER (Please specify).

_____

C16h. For this trip did you
1. Rent
2 Borrow
3. Purchase
4. Or already own this equipment?
5. DON'T KNOW
43

Y. DON'T KNOW

C17. On your last camping trip were you generally satisfied or generally dissatisfied with: (INTERVIEWER: READ EACH STATEMENT BELOW AND CIRCLE RESPONDENT'S ANSWER.)

	GENERALLY SATISFIED	GENERALLY DISSATISFIED	DON'T KNOW	DOES NOT APPLY TO MY STYLE OF CAMPING	
A. The availability of tentsites and trailersites	1	2	3	4	44
B. The availability of recreational facilities at the campground	1	2	3	4	45
C. The cleanliness and condition of campgrounds	1	2	3	4	46
D. The availability of hook-ups	1	2	3	4	47
E. The level of camping fees	1	2	3	4	48
F. The trip as a whole	1	2	3	4	49

C18. On your last trip did you camp at privately-owned campgrounds, publicly-owned campgrounds, such as federal or state parks, or both public and private?

1 PRIVATELY-OWNED
2 PUBLICLY-OWNED
3 BOTH
4 DON'T KNOW

50

C19. On your last camping trip, can you recall how many days you were away from home?

_____DAYS
X DON'T KNOW

51-52

C20. Thinking back to the year that you last went camping, approximately how many camping trips did you go on during that year?

_____TRIPS
X DON"T KNOW

53

C21. And, about how many days did each trip last on the average?

_____DAYS
X DON'T KNOW

54-55

INTERVIEWER: ALL RESPONDENTS ARE ASKED THE FOLLOWING QUESTIONS.
SHOW EXHIBIT C-22

C22. During the next year, which of the following types of equipment do you expect to purchase? Just read me the numbers, please. (Circle each item answered.)

1 2 3 4 5 6 7 8 9 10 56

11 12 13 14 15 16 OTHER (Please specify):_____ 57
17 NONE OF THESE
18 DON'T KNOW

SHOW EXHIBIT C-23

C23. Many campgrounds are provided on public lands such as State and National Parks. Here are two opposite ideas about fees for camping at these public parks. Which of these statements do you most agree with?

1 FEES COVER ALL COSTS
2 FEES KEPT LOW
3 NO OPINION

58

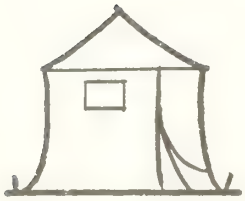
SHOW EXHIBIT C-24

C24. During the past 12 months have you, personally, participated in any of the following types of leisure time activities? Just read me the numbers, please.

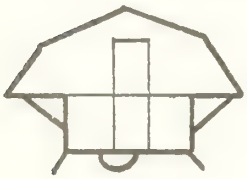
1 BOATING (motor boats)
2 CANOEING
3 FISHING
4 HIKING
5 SKIING (on snow)
6 PICNICKING (away from home)
7 SWIMMING (away from home)
8 TRAIL BIKE RIDING OR SNOWMOBILING
9 HUNTING (any type, any place)
10 BACK PACKING
X NONE OF THE ABOVE
Y DON'T RECALL

59

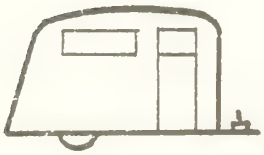
EXHIBIT C-1



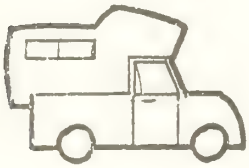
1 TENT (Any kind, any size)



2 CAMPING TRAILER (Folding)

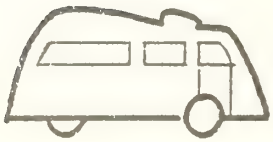


3 TRAVEL TRAILER (Any kind, any size)



4 TRUCK CAMPER

5 PICK-UP COVER



6 MOTOR HOME

7 VAN OR BUS CONVERSION

LaPage, W. F. and G. L. Cole.
1979. **The 1978 national camping market survey.** Northeast. For. Exp. Sta., Broomall, PA.
34 p. (USDA For. Serv. Res. Pap. NE-450)

A study of the camping market's short-term growth potential, based upon interviews with the heads of 2,013 representative American households. The study estimates the size of the potential camping market and divides it into three segments: those families with a high, medium, or low potential for entering the camping market. The developed camping market also is divided into an active and an inactive segment, determined by camping participation during the 12 months preceding the survey. The total camping market includes an estimated 17.5 million active camping families, 20.5 million inactive, and 4.5 million potential camping families. Regional distributions and characteristics of each segment are described.

907.2

Keywords: recreation participation, recreation vehicles, trend measurement

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907.2

Keywords: recreation participation, recreation vehicles, trend measurement

Example:

A warm day	1	2	3	4	5	A cold day

EXHIBIT C-4

I think camping would be:

A. . . . . Interesting	1	2	3	4	5	Boring
B. . . Unfriendly people	1	2	3	4	5	Friendly people
C. . . . . Clean	1	2	3	4	5	Dirty
D. . . . . Dangerous	1	2	3	4	5	Safe
E. . . . . .Refreshing	1	2	3	4	5	Tiring
F. . . . . Crowded	1	2	3	4	5	Uncrowded
G. . . . . Expensive	1	2	3	4	5	Not expensive
H. . . . . Difficult	1	2	3	4	5	Easy
I. . . . . .Pleasant	1	2	3	4	5	Unpleasant
J. . . . . .Work	1	2	3	4	5	Fun
K. . . . . .Convenient	1	2	3	4	5	Not convenient
L. . . . . Complicated	1	2	3	4	5	Easy
M. . . . . Uncomfortable	1	2	3	4	5	Comfortable

EXHIBIT C-7

Reasons for deciding not to camp

1 The expected costs of camping

2 We lacked information about camping equipment

3 We lacked information about places to camp

4 We were uncertain about whether we would enjoy associating with campers

5 We could not find enough time

6 Other reasons (please specify)

EXHIBIT C-8

1 We expect to go camping next year

2 We hope to go camping at some time in the future, but probably not next year

3 We are unlikely to go camping in the foreseeable future

4 We are definitely not interested in camping

EXHIBIT C-145

1 Because of personal or family reasons

2 Increased costs of camping

3 Unfavorable weather conditions

4 Loss of interest in camping

5 Lack of time

6 Other reasons (please specify)

EXHIBIT C-22

Next year I expect to buy:

1 FISHING EQUIPMENT

2 SNOWMOBILE

3 CANOE

4 SKIING EQUIPMENT

5 MOTOR BOAT

6 HUNTING EQUIPMENT

7 TRAIL BIKE -- OR OFF-ROAD RECREATIONAL VEHICLE

8 HIKING EQUIPMENT

9 BACK PACK

10 SLEEPING BAGS

11 CAMP STOVE

12 TRAILER OR TENT HEATER

13 LIGHT WEIGHT, MOUNTAINEERING TENT

14 COOLER CHEST OR REFRIGERATOR

15 GAS OR PROPANE LANTERN

16 OTHER (please specify)

EXHIBIT C-23

1 Camping fees should be set high enough to cover all -- or most -- of the costs of operating a public campground

2 Camping fees on public lands should be kept low and most of the costs of operating campgrounds should be paid out of our taxes

EXHIBIT C-24

1 BOATING (MOTOR BOATS)

2 CANOEING

3 FISHING

4 HIKING

5 SKIING (ON SNOW)

6 PICNICKING (AWAY FROM HOME)

7 SWIMMMING (AWAY FROM HOME AND OUTDOORS)

8 TRAIL BIKE RIDING OR SNOWMOBILING

9 HUNTING (ANY TYPE, ANY PLACE)

10 BACK PACKING

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Table 1.—Distribution of active, temporarily inactive, and potential camping households, by region, 1973-1978,[a] in millions

Region	Total households		Camping market households					
			Active		Temporarily inactive[b]		Potential[c]	
	1973	1978	1973	1978	1973	1978	1973	1978
Northeast	16.4	17.3	2.3	3.3	1.0	1.8	2.1	1.1
North Central	18.4	20.1	3.2	4.9	2.1	2.2	1.2	1.1
South	21.2	24.2	4.8	4.6	2.0	3.0	2.2	1.9
West	12.3	14.4	4.0	4.7	1.2	2.1	0.6	0.4
United States[d]	68.3	76.0	14.3	17.5	6.1	9.1	6.1	4.5

[a]For an approximate estimate of total persons (campers), multiply 1973 households by 3.01 persons per household, and 1978 households by 2.81.

[b]Temporarily inactive campers have not camped for 3 years *or* longer. If longer, they said that they had not quit. In 1973 there were an additional 7.5 million permanently inactive households which had increased to 11.4 by 1978.

[c]This includes "high" and "moderate" potential for camping; that is, those who plan to camp or who have a distinct interest in trying it. In 1973 there were an additional 34 million households with little or no interest in camping—by 1978 this figure had not changed significantly.

[d]*Northeast:* Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania
North Central: Ohio, Indiana, Illinois, Michigan, Wisconsin Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas
South: Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma, Texas
West: Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada, Washington, Oregon, California

Table 2.—Size of the American camping market in 1971, 1973, and 1978, as a percentage of total households

Market class	1971	1973	1978
Camper:			
Active	19	21	23
Temporarily inactive	5	9	12
Permanently inactive	9	11	15
Noncamper:			
High potential	3	1	1
Medium potential	9	8	5
Low potential	4	17	18
Zero potential	51	33	26

Table 3.—Average annual growth in the numbers of active, inactive, and potential campers, and new households in the United States, during the periods 1971-1973 and 1973-1978, in percent

Market class	Average annual growth	
	1971-1973	1973-1978
Camper:		
Active	+ 7.6	+ 4.5
Temporarily inactive	+42.4	+ 9.8
Permanently inactive	+14.7	+10.4
All campers	+14.9	+ 7.2
Noncamper:		
High and medium potential	−10.4	− 5.2
Low and zero potential	− 2.5	0
All noncampers	− 3.9	− 1.0
New households in United States	+ 2.3	+ 2.4

Table 4.—Type of shelter used by active campers on last camping trip, 1971, 1973, and 1978, in percent

Shelter[a]	1971	1973	1978
Tent	50	41	42
Camping trailer	13	11	11
Travel trailer	17	17	19
Truck camper	15	15	12
Motor home	3	7	9
Van or converted bus	6	10	10
Pickup cover	6	5	11
Other	—	5	4
Unknown	—	1	1

[a]Totals exceed 100 percent because some campers use more than one type of shelter on a camping trip.

Table 5.—Recreational vehicle shipments, 1970-1978

Year	Camping trailer	Truck camper	Motor home	Travel trailer	Total shipment	Change from preceding year
			Percent		*Thousands*	*Percent*
1970	31	25	8	36	380	− 5.2
1971	21	24	13	42	451	+18.7
1972	19	18	20	43	583	+29.3
1973	19	17	24	40	529	− 9.3
1974	19	15	23	43	296	−44.1
1975	14	13	29	44	340	+14.9
1976	12	10	35	43	441	+29.7
1977	13	8	39	41	414	− 6.1
1978	12	6	40	41	390	− 5.8

Table 6.—Percentage of active campers who rented, borrowed, bought, or already owned camping equipment, 1971, 1973, and 1978

Source	1971	1973	1978
Rent	8	7	2
Borrow	32	28	25
Buy	10	5	4
Already own	50	60	69

Table 7.—Disposition of camping equipment by inactive campers in 1973 and 1978, in percent

Disposition	Inactivity class			
	Temporary		Permanent	
	1973	1978	1973	1978
Sold it	7	12	17	13
Gave it away	2	4	7	7
Still have it	28	27	18	18
Never owned any[a]	40	34	53	58
Don't know	3	6	6	5
Total asked	80[b]	83[b]	100	100

[a]Equipment used when camper was active either rented or borrowed.

[b]The remaining respondents did not consider themselves as inactive.

Table 8. — Percentage of campers who camped at privately owned or publicly owned campgrounds, or both, on their last camping trip

Campground	1973	1978
Active		
Private	26	34
Public	51	44
Both	18	16
Temporarily inactive		
Private	32	28
Public	52	50
Both	13	19

Table 9.—Percentage of campers who entered the camping market within each of the past 4 years.

Year began camping	Survey year		
	1971	1973	1978
This year	8	6	4
Last year	9	7	4
2 years ago	25	8	6
3 years ago	21	8	6
Over 3 years ago	26	58	71
Don't recall	11	13	9

Table 10.—Recent trends in camping participation by campers who began camping before each survey year (1973, 1978), in percent

Camper group	About the same each year		Increased lately		Decreased lately	
	1973	1978	1973	1978	1973	1978
All campers	20	17	16	22	50	54
Campers without children	20	13	13	16	51	59
Campers with children	20	19	18	26	48	50
Currently active campers	31	25	28	40	26	24
Head of household under 30	19	15	16	20	45	54
Head of household 30-39	21	19	22	30	45	43
Head of household 40-49	22	24	13	27	53	46
Head of household 50-59	20	21	13	15	56	61
Head of household 60 or older	13	8	12	15	60	70
Northeast	20	25	18	29	53	42
North Central	15	16	16	22	54	50
South	23	13	12	18	43	61
West	19	16	20	22	50	56

Table 11.—Frequency of camping participation by active campers, in 1978, and by inactive campers before 1978

Category	Active	Inactive	
		Temporary[a]	Permanent[b]
Average length of last camping trip (days)	5.6	5.3	5.6
Average number of trips in last camping year	3.4	2.2	1.7
Average number of days camped per trip last camping year	4.7	4.9	5.2
Average number of days camped in last camping year	16	11	9

[a]In general, their last camping trip would have been sometime during the period 1975-1977.
[b]Have not camped for at least 3 years.

Table 12.—Income distribution for active, inactive, and potential campers in 1973 and 1978, in percent

Household income	United States[a]		Active		Inactive[b]		Potential	
	1973	1978	1973	1978	1973	1978	1973	1978
Under $7,000	30	26	22	15	25	21	28	26
$7,000 to $10,000	19	11	19	13	22	11	18	10
$10,000 to $15,000	26	18	29	24	30	18	29	21
$15,000 to $25,000	20	26	26	31	19	27	21	28
Over $25,000	6	15	5	15	4	19	4	15

[a]Based on total sample distribution in the 1978 camper survey, 2,013 households.
[b]Includes temporarily inactive campers only (12 percent of households).
[c]Includes both high and medium potential campers, totaling 6 percent of all households.

Table 13.—Age distribution for active, temporarily inactive, and potential campers in 1973 and 1978, in percent

Head-of-household's age	United States		Active		Inactive		Potential	
	1973	1978	1973	1978	1973	1978	1973	1978
18-29	27	30	44	41	38	55	42	39
30-39	19	19	25	28	23	15	26	22
40-49	15	14	12	14	15	14	17	20
50-59	15	14	10	9	15	8	8	14
60 or older	24	23	9	8	9	8	7	5

Table 14.—Demographics of the camping market in 1978, in percent

Characteristic	U.S. public[a]	Camping household		
		Active	Inactive[b]	Potential[c]
Age of head of household:				
18-29 years	30	41	55	38
30-39	18	28	15	22
40-49	14	14	14	20
50-59	14	9	8	14
60	23	8	8	5
Education:				
Less than high school	33	26	23	35
High school	38	42	41	42
Some college	17	20	23	13
Occupation:				
Executive, professional, manager	15	17	17	14
White collar	23	26	26	25
Skilled	19	27	22	19
Semiskilled	20	19	22	37
Retired	19	8	10	3
Place of residence:				
Rural	17	17	17	6
Urban (nonmetro)	16	19	11	20
Metro (50,000-999,999)	33	35	38	40
Metro (1,000,000 or over)	34	29	34	33
Region:				
Northeast	23	19	19	25
North Central	27	27	23	24
South	32	26	34	43
West	18	27	23	8
Income:				
Under $7,000	26	15	21	26
$7,000 - $9,999	11	13	11	10
$10,000 - $14,999	18	24	18	21
$15,000 - $24,999	26	31	27	28
$25,000 or over	15	15	19	15
Race:				
White	88	97	93	83
Nonwhite	12	3	7	17
Family composition:				
No children in household	43	34	34	19
With children under 18	52	63	63	81
Home ownership:				
Own	68	68	54	65
Rent	30	32	42	35

[a]Based on a sample of 2,013 households surveyed in December, 1978.
[b]Temporarily inactive only.
[c]High and medium potential only.

Table 15.—Marital status, family composition, and race of active, inactive, and potential campers 18 years old and older, 1973-1978, in percent

Camper group	Marital status			Family composition	Race	
	Married	Widowed, divorced, separated	Never married	No children	White	Nonwhite
Active						
1973	80	8	12	40	98	2
1978	75	8	16	34	97	3
Temporarily inactive						
1973	83	8	9	40	97	3
1978	62	11	26	34	93	7
Permanently inactive						
1973	79	12	9	57	96	5
1978	70	16	13	49	92	8
Potential						
1973	86	6	8	23	83	17
1978	79	11	9	19	72	28
Low and zero potential						
1973	74	20	6	59	88	12
1978	70	18	11	55	83	17
Total U.S.						
1973	78	14	8	50	89	11
1978	71	14	14	43	88	12

Table 16.—Percentage of selected camping groups with a favorable or unfavorable image of camping's environment, conditions, and attractions, 1973 and 1978

Image	Total U.S.		Active		Temporarily inactive		Potential	
	1973	1978	1973	1978	1973	1978	1973	1978
Environment:								
Favorable[a]	52	55	80	81	72	75	72	68
Unfavorable[b]	18	16	9	8	14	10	10	12
Conditions:								
Favorable[c]	35	35	49	50	42	40	42	41
Unfavorable[d]	22	22	18	18	20	23	23	25
Attraction:								
Favorable[e]	35	36	58	60	50	44	49	40
Unfavorable[f]	28	26	15	15	22	21	20	23

[a]Composite of interesting, friendly, refreshing, pleasant.
[b]Composite of boring, unfriendly, tiring, unpleasant.
[c]Composite of clean, safe, uncrowded, inexpensive.
[d]Composite of dirty, dangerous, crowded, expensive.
[e]Composite of easy, fun, convenient, comfortable.
[f]Composite of difficult, work, inconvenient, uncomfortable.

Table 17.—Percentage of camping market households with a positive image of camping, 1973-1978

Image description	Camping market household											
	All		Active		Temporarily inactive		Permanently inactive		High and medium potential		Low and zero potential	
	1973	1978	1973	1978	1973	1978	1973	1978	1973	1978	1973	1978
Environment:												
Interesting	55[a]	57	86	88	79	77	65	56	83	74	30	34
People friendly	59	59	78	79	66	75	69	59	64	57	47	44
Refreshing	44	47	73	71	70	68	47	41	62	58	21	26
Pleasant	52	57	81	84	73	79	63	59	81	81	27	32
Composite	52	55	80	81	72	75	61	54	72	68	31	34
Conditions:												
Clean	34	34	54	52	39	36	40	30	47	49	21	21
Safe	43	42	64	62	60	53	45	44	45	49	30	27
Uncrowded	25	26	29	34	26	30	36	25	35	26	19	21
Inexpensive	37	37	50	52	44	42	41	37	40	41	28	27
Composite	35	35	49	50	42	40	40	34	42	41	24	24
Attraction:												
Easy	35	35	56	62	47	40	36	37	50	41	21	18
Fun	40	39	62	57	56	46	45	45	57	42	23	25
Convenient	27	32	47	53	40	39	31	36	35	37	15	16
Comfortable	39	39	65	67	56	49	43	43	54	39	20	20
Composite	35	36	58	60	50	44	39	40	49	40	20	20
Number of respondents	2,199	2,013	450	423	214	238	281	318	198	109	1,056	908

[a]In 1973, 55 percent of the U.S. public felt that camping was interesting; that is, they assigned a 1 or 2 on a scale of 1 to 5 (1 being the most positive, 5 being the most negative).

Table 18.—Percentage of camping market households with a negative image of camping, 1973-1978

Image description	All		Camping market household: Active		Temporarily inactive		Permanently inactive		High and medium potential		Low and zero potential	
	1973	1978	1973	1978	1973	1978	1973	1978	1973	1978	1973	1978
Environment:												
Boring	19[a]	15	6	3	10	8	15	17	3	6	30	26
People unfriendly	11	12	11	11	16	11	10	17	17	23	3	11
Tiring	25	23	10	9	18	11	28	28	15	16	35	33
Unpleasant	18	15	8	9	13	9	15	16	7	2	26	23
Composite	18	16	9	8	14	10	17	20	10	12	24	23
Conditions:												
Dirty	22	19	15	12	17	24	23	19	15	17	26	22
Dangerous	15	16	9	16	10	14	17	17	21	18	16	18
Crowded	32	32	32	27	35	34	38	42	35	43	29	29
Expensive	18	22	15	17	17	22	19	26	21	21	18	23
Composite	22	22	18	18	20	23	24	26	23	25	22	23
Attraction:												
Difficult	25	26	13	16	24	24	30	28	22	25	29	29
Work	26	25	18	18	21	20	26	26	18	24	32	32
Inconvenient	33	28	19	17	24	21	36	32	26	23	40	34
Uncomfortable	26	23	11	10	18	18	28	23	12	22	35	31
Composite	28	26	15	15	22	21	30	27	20	23	34	32
Number of respondents	2,199	2,013	450	423	214	238	281	318	198	109	1,056	908

[a] In 1978, 19 percent of the U.S. public felt that camping was boring; that is, they assigned a 4 or 5 rank on the scale of 1 to 5.

Table 19.—Image indexes[a] for selected demographic and camping market classes, 1973-1978

Item	1973		1978	
	Number	Image index	Number	Image index
Total U.S.	2,207	1.69	2,013	1.97
Sex:				
Male	1,067	1.99	995	2.29
Female	1,116	1.44	1,018	1.67
Age:				
18-29 years	590	2.56	569	2.50
30-39	418	1.61	411	1.94
40-49	327	1.52	287	1.89
50-59	331	1.46	265	1.72
60 or older	529	1.25	481	1.50
Education:				
Less than high school	758	1.73	561	2.13
High school	757	1.77	689	1.84
Some college	676	1.57	421	2.04
Place of residence:				
Rural	310	1.68	194	2.26
Urban (nonmetro)	307	1.98	209	1.83
50,000-999,999	651	1.77	656	2.21
1,000,000 or more	939	1.57	954	1.70
Region:				
Northeast	516	1.35	485	1.94
North Central	620	1.62	561	1.61
South	724	1.80	602	2.02
West	347	2.23	365	2.47
Income:				
Under $7,000	656	1.96	363	1.90
$7,000-$9 999	413	1.87	262	2.04
$10,000-$14,999	560	1.63	343	2.44
$15,000 or more	548	1.41	974	1.76
Race:				
White	1,979	1.67	1,775	2.00
Nonwhite	188	1.97	236	1.88
Family size:				
No children	1,102	1.61	972	1.87
Children under 18	1,105	1.77	907	2.02
Home ownership:				
Own	1,514	1.53	1,364	1.80
Rent	664	2.13	620	2.37
Camping group:				
Active	450	4.27	423	4.61
Temporarily inactive	213	2.94	238	2.94
Permanently inactive	295	1.85	318	1.79
High and medium potential	181	2.62	109	2.54
Low and zero potential	1,053	0.84	908	0.99

[a]The image index is the number of persons in each group who have a generally favorable image of camping for each person who has a generally unfavorable image.

Table 20.—Camper satisfaction or dissatisfaction with last camping trip, 1973 and 1978, in percent

Degree of satisfaction[a]	Active		Temporarily inactive		Permanently inactive	
	1973	1978	1973	1978	1973	1978
Overall trip:						
Generally satisfied	93	93	89	91	73	78
Generally dissatisfied	4	5	8	8	16	14
Does not apply to my camping style	2	1	2	1	6	4
Campsite availability:						
Generally satisfied	78	78	75	83	63	71
Generally dissatisfied	9	11	12	9	13	15
Does not apply to my camping style	12	10	11	8	18	9
Hookup availability:						
Generally satisfied	53	48	54	54	39	52
Generally dissatisfied	5	8	7	8	7	9
Does not apply to my camping style	38	43	33	33	40	36
Recreation facilities:						
Generally satisfied	73	72	71	72	55	66
Generally dissatisfied	11	11	12	14	14	15
Does not apply to my camping style	15	15	15	13	24	13
Cleanliness and condition of campground:						
Generally satisfied	78	80	76	76	65	72
Generally dissatisfied	12	9	13	13	15	13
Does not apply to my camping style	9	11	9	8	15	10
Level of camping fees:						
Generally satisfied	70	66	70	75	54	65
Generally dissatisfied	9	11	8	6	5	8
Does not apply to my camping style	17	20	16	13	25	16

[a]Totals do not equal 100 percent in most cases because of nonresponses.

Table 21.—Attitude toward the total cost[a] of camping compared with other ways of traveling and taking a vacation, 1973 and 1978, in percent[b]

Camping group	More economical		Less economical	
	1973	1978	1973	1978
U.S. public	43	46[b]	14	14[b]
Active	66	67	13	13
Temporarily inactive	51	72	18	9
Permanently inactive	45	49	18	19
High-potential households	51	40	15	5
Medium-potential households	53	47	9	13
Low-potential households	36	32	16	15
Zero-potential households	27	24	11	16

[a]Respondents were asked to visualize the total cost of camping as including taxes on equipment, campsite fees, extra tolls, insurance, and other equipment costs.
[b]Totals for each year do not equal 100 percent due to many respondents reporting "no opinion."

Table 22.—Opinion of respondents concerning public campground fees, 1973 and 1978, in percent

Camping group	Fees should cover all costs		Fees should be kept low		No opinion	
	1973	1978	1973	1978	1973	1978
Active	43	43	51	52	6	5
Temporarily inactive	56	57	37	32	7	10
Permanently inactive	49	48	34	38	17	13
High potential	52	20	42	69	6	11
Medium potential	48	52	45	26	7	22
Low potential	36	37	30	30	34	32
Zero potential	31	31	20	20	49	49
Total	40	42	34	34	26	24

Table 23.—Percentage of active and temporarily inactive campers and the adult public participating in selected recreation activities, 1973 and 1978

Recreation activity	Active		Temporarily inactive		Total U.S. adults[a]	
	1973	1978	1973	1978	1973	1978
Picknicking away from home	70	73	62	76	48	49
Swimming away from home	63	74	60	62	43	45
Fishing	65	63	55	49	37	35
Motorboating	49	48	37	41	25	24
Hiking	45	44	30	28	18	19
Hunting	34	26	31	21	15	13
Trail bike use/ snowmobiling	22	17	14	19	9	9
Canoeing	12	18	13	13	6	8
Snow skiing	11	14	7	15	5	7
Backpacking	14	13	8	5	4	5
None of the above	3	3	8	7	23	28

[a]From the 1973 and 1978 National Camping Market Surveys—asked of all respondents, campers and noncampers.

Table 24.—Percentage of respondents who visited a camping or recreational vehicle show within the past 2 years, and who have friends who own camping equipment, 1973 and 1978

Market group	Visited camping show		Camping friends	
	1973	1978	1973	1978
Camper				
Active	51	44	94	94
Temporarily inactive	34	39	90	90
Permanently inactive	22	23	77	73
Noncamper				
Potential	26	23	68	51
Low and zero potential	9	6	36	37
Total households	23	22	60	62

Table 25.—Incidence of and reasons for trip cancellations by active, temporarily inactive, and permanently inactive campers in 1978, in percent

Category	Active	Temporarily inactive	Permanently inactive
Cancelled or shortened a trip, or postponed purchase of camping equipment[a]	30	22	8
Reason:			
Personal or family	9	5	2
Cost	1	1	2
Weather	10	4	1
Lost interest	2	1	1
Lack of time	7	8	4
Other	6[b]	7	—

[a]A similar question about the specific effects of the 1973 gas shortage was asked in the 1973 survey, and resulted in answers of 11 percent for active campers, 6 percent for temporarily inactives, and 4 percent for permanently inactives.

[b]Totals exceed the percent listed above due to multiple reasons given.

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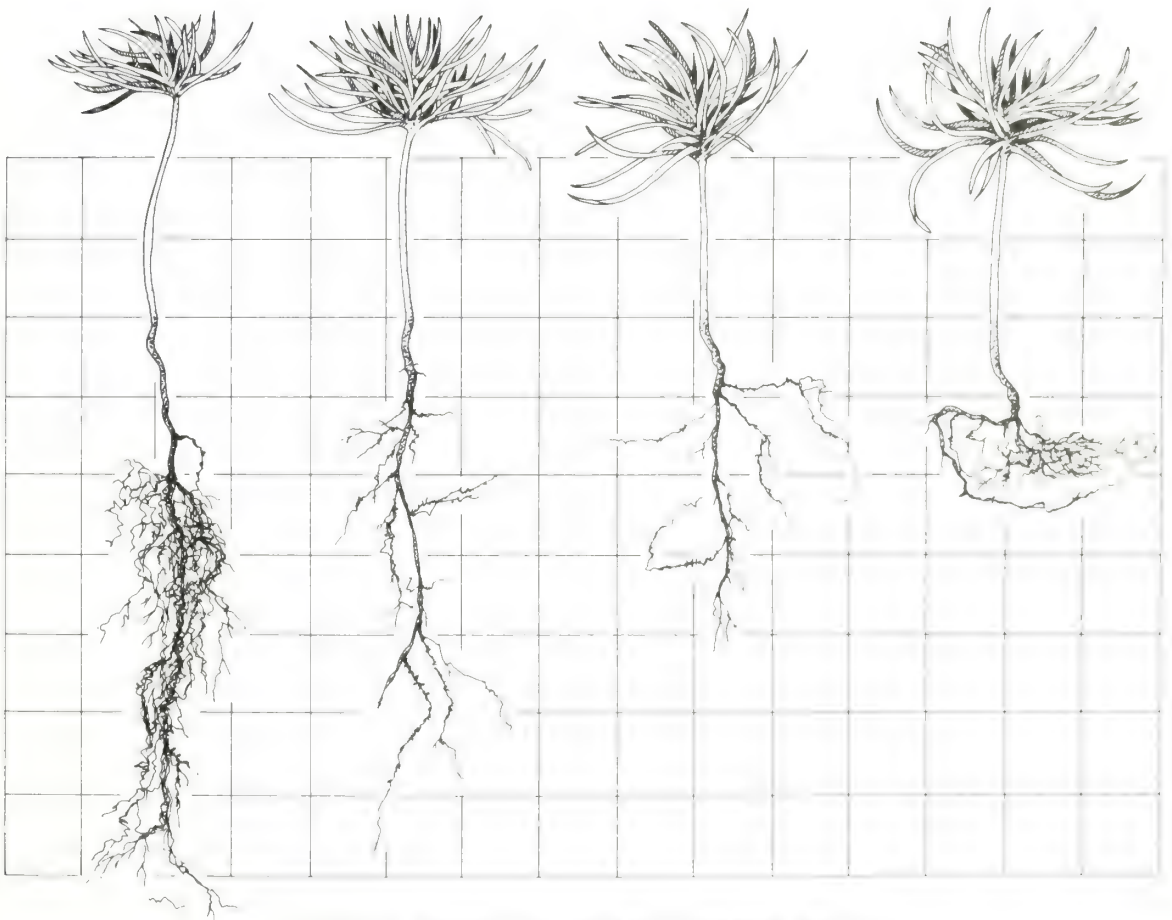
ESTABLISHMENT AND EARLY GROWTH OF CONIFERS ON COMPACT SOILS IN URBAN AREAS



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Abstract

A study of pitch pine, Austrian pine, and Norway spruce on two different urban soils compacted to bulk densities of 1.2, 1.4, 1.6, and 1.8 $g \cdot cm^{-3}$ and maintained at high water potentials showed that all three species could become established from seed at high soil bulk densities. Pitch pine was the most successful species in establishment. Only a silt loam soil, packed to a bulk density of 1.8 $g \cdot cm^{-3}$, significantly reduced establishment of all three species. A sandy loam soil, also packed to 1.8 $g \cdot cm^{-3}$, did not reduce establishment. Root penetration was restricted at a bulk density of 1.4 $g \cdot cm^{-3}$ on the silt loam and 1.6 $g \cdot cm^{-3}$ on the sandy loam; there was a strong interaction between bulk density and soil type. Measured soil resistance to penetration may be a better indicator than bulk density for predicting seedling performance.

INTRODUCTION

THERE HAS BEEN INCREASING PRESSURE to use forest lands in and near urban centers to provide amenities for people. Forest vegetation within cities is often collectively referred to as the urban forest. Andresen (1978) distinguishes inner-city forests from adjacent surrounding forests by calling the latter urbanizing forests. The difference is important because different forest management practices may be needed in each area to moderate the impact of people on the forest.

Human use of the forest for amenity purposes, such as recreation, has a variety of impacts. Under light initial use, the impact is small; natural processes can restore the site to original conditions. Near urban centers, continued and heavier use is the rule, and additional impacts appear. It is difficult to quantify the degree of impact near urban centers because there are few, if any, undisturbed areas which can be examined to define initial conditions. Isolated high-use areas, such as recreation sites in wilderness areas, can be used to gain some insight into the problem. A recent article (Frissell 1978) defined five condition classes and possible management actions to restore wilderness area campsites. One of the first significant conditions to develop with continued use is soil compaction. As use intensifies, soils become more compacted, the site deteriorates, erosion increases, and trees begin to die. As site conditions worsen, rehabilitation becomes more difficult.

While it is ofen mentioned that compacted soil is common in urban areas, few investigations have been made to determine accurately the extent of the problem. One of the few pieces of quantitative information that documents the degree of soil compaction in metropolitan areas comes from a survey of soils located in the Washington, D.C. area (Patterson 1976). Compaction of several different soils resulted in an increase in bulk density from a range of 1.30 to 1.60 $g \cdot cm^{-3}$ to a range of 1.70 to 2.20 $g \cdot cm^{-3}$. Even this small amount of information clearly indicates the potential for serious soil compaction problems in urban areas.

Although we speak of certain urban soils as compacted, the term is qualitative. Compaction alone does not describe accurately the effect of compacted soils on vegetation. Associated with the compaction process are changes in total pore space, distribution of pore sizes, and resistance to penetration that may affect tree establishment and growth.

Although there are several descriptions of the effect of compact soils on trees and roots (Meinecke 1929; McQuilkin 1935; Lutz et al. 1937; Youngberg 1959), there have been relatively few quantitative investigations from which specific recommendations can be made. To date, several coniferous tree species have been used for most studies in the western United States (Forristall and Gessel 1955; Minore et al. 1969) and loblolly pine (*Pinus taeda*) has been used for most studies in the Southeast (Pomeroy 1949; Perry 1964; Foil and Ralston 1967; Hatchell 1970; Duffy and McClurkin 1974). Little work has been done with deciduous tree species except by Korstian (1927) and Broadfoot and Bonner (1966). The highly variable and sometimes conflicting results illustrate the need for research conducted under more controlled conditions.

There is an inverse relationship between the total porosity of a soil and its bulk density. The use of total porosity as an index of soil compaction is similar to the use of bulk density. However, since most movement of air and water takes place in the soil macropores, the distribution of pore sizes is of more interest than the total porosity. In general, soil aeration does not become limiting until the macroporosity is reduced to less than about 10 percent (Baver et al. 1972). In addition, a direct influence of pore size on the physical resistance which a soil offers a growing root has been suggested (Wiersum 1957).

The resistance of soil to penetration by a probing instrument (Penetrometer) is an integrated index of several soil properties including texture, structure, density, consistency, moisture content, and degree of compaction. It is an index of soil strength under the conditions of the measurement (Baver et al. 1972). Although the amount of penetration per unit force applied to a given soil will vary with the shape and kind of penetrometer used (Baver et al. 1972), the pattern of resistance to penetration is not affected. Also, penetrometer measurements have been shown to be highly correlated with standard laboratory determinations of soil strength (Taylor and Burnett 1964). Soil moisture appears to be the dominant factor influencing the strength of a given soil. There is a rapid increase in resistance with decreasing moisture (Eavis 1972).

Urban site rehabilitation on compacted soils often includes tree planting. The plants considered are usually nursery stock which is several years old and a few meters tall. The process used to select trees is given in a theoretical example by Rex (1976). Planting larger trees is labor-intensive and may well not be economically feasible for forest tracts surrounding cities. Consequently, alternative methods of urban forest establishment are needed, and direct seeding is one method that should be evaluated.

This study was conducted to evaluate the effects of two highly compacted urban soils on the establishment and early growth of several tree species grown from seed. The species chosen are either native or widely planted in the urbanized Northeast.

MATERIALS AND METHODS

Two medium-textured soils (silt loam and sandy loam) found in the Northeast urban corridor were used in this study. The silt loam was taken from an area classified as a poorly drained variant of the Nixon soil series and the sandy loam was taken from an area classified as part of the Lakewood soil series. Both soils were analyzed for physical and chemical properties:

Property	*Silt loam*	*Sandy loam*
Texture (%)		
Sand	22	66
Silt	64	26
Clay	14	8
pH	4.0	4.3
Organic matter (% dry weight)	7.52	3.60
Total nitrogen (% dry weight)	0.2090	0.0825
Available nutrients (ppm)		
Phosphorous	10	33
Potassium	30	18
Magnesium	20	16
Calcium	0.75	1.00

Cast acrylic tubes were used as growing containers. The tubes were 22.5 cm (8.9 inches) in length and had an inside diameter of 6.35 cm (2.5 inches). A perforated plate was secured to the bottom of each tube to allow for drainage.

Samples from each soil type were packed into individual containers to give four levels of bulk density: 1.2, 1.4, 1.6, and 1.8 $g \cdot cm^{-3}$. The soil was compacted in 1-cm (0.4-inch) increments in an attempt to create a soil column of uniform density. The total height of each soil column was 15.0 cm (5.9 inches).

Laboratory determinations of distribution of pore sizes, amount of water retained at ⅓ bar tension, and resistance of the soil to penetration at this moisture content were made for each combination of soil type-bulk density treatment (Table 1). Total porosity was separated into macro- and micro-porosity on the basis of the pore size that would hold water

Table 1.—Distribution of pore sizes and resistance to penetration of two soil types at different bulk densities

Bulk density	Pore Size		Resistance to penetration
	Macro	Micro	
$g \cdot cm^{-3}$	%		*bar*
	SILT LOAM		
1.2	24.2	30.5	1.4
1.4	19.0	28.2	2.5
1.6	16.8	22.8	4.7
1.8	14.6	17.5	9.4
	SANDY LOAM		
1.2	41.2	13.5	0.6
1.4	28.9	18.3	1.2
1.6	23.7	15.9	2.4
1.8	18.6	13.5	3.7

Macropores were defined as pores that would not retain water at ⅓ bar tension. Micropores retained water at ⅓ bar tension.

under ⅓ bar tension. Resistance of the soil to penetration was determined with a hand-held penetrometer at the low levels of compaction and with a Proctor[1] penetrometer at the high levels.

The genera *Picea* and *Pinus* are the most often planted conifers in the urban Northeast (Gerhold et al. 1975). Stratified seeds of pitch pine (*Pinus rigida* Mill.), Austrian pine (*Pinus nigra* Arnold), and Norway spruce (*Picea abies* (L.) Karst) were obtained from a state nursery, soaked in water for 24 hours, and treated with a fungicide solution to control damping off. For each species, 20 seeds were then sowed on top of the appropriate compacted soil column and covered with a thin layer of sphagnum moss to prevent desiccation and to offer further protection from damping off.

The containers were placed on a greenhouse bench in a randomized complete block design with 24 treatment combinations and 4 replications. Soil-water availability in each container was maintained near ⅓ bar of tension for the duration of the study (October to February). Natural day length was extended by artificial light for 4 hours at the end of each day. Ambient air temperatures in the greenhouse varied between 16° and 34°C (60° and 94°F), and the relative humidity ranged from 26 to 98 percent.

After 1 month, the percentage of radicles that successfully penetrated the soil was recorded for each container. The number of seedlings was then reduced to one per container. These seedlings were allowed to grow for an additional 3 months at which time they were harvested by carefully washing the soil from the roots.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

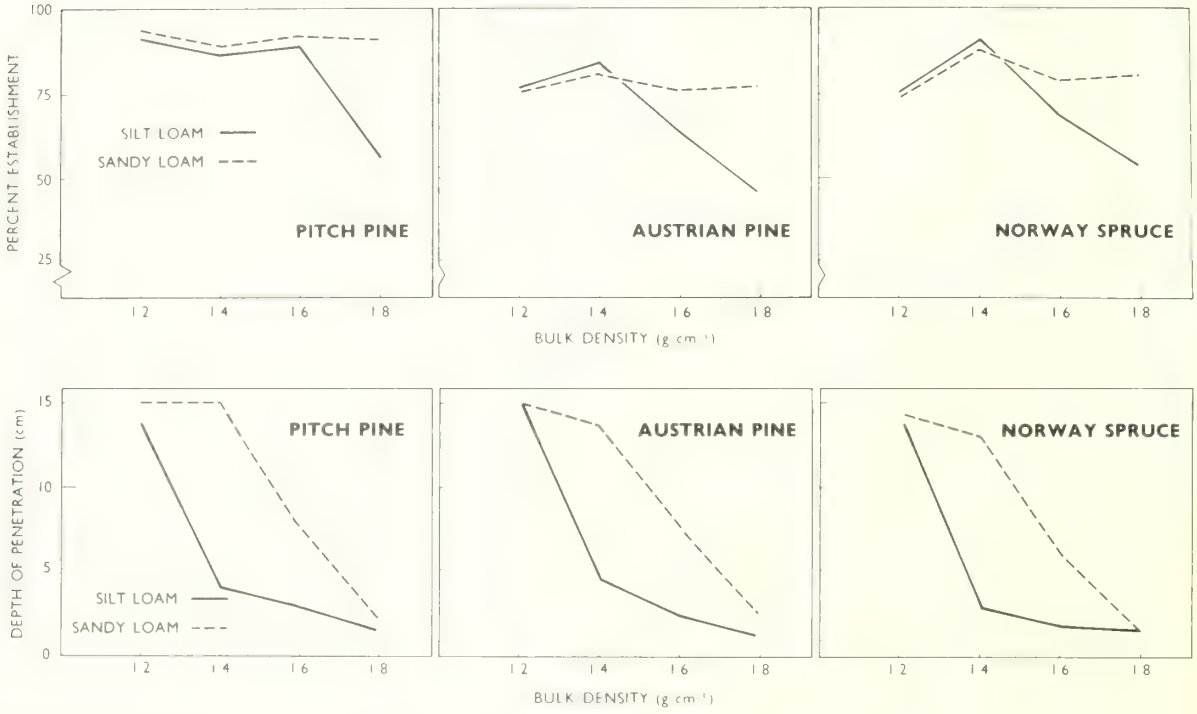
RESULTS

All data were subject to analysis of variance. The arcsine transformation (Zar 1974) was applied to percent establishment responses for purposes of statistical analysis. To make specific comparisons between certain treatment means, the honestly significant difference (hsd) multiple comparison procedure was used (Steel and Torrie 1960). All responses were reported as statistically significant at the $p < .05$ level.

Seedling establishment

The percent establishment of pitch pine seedlings was significantly greater than either Austrian pine or Norway spruce when averaged over soil type and bulk density; pitch pine establishment was 85 percent, Norway spruce was 76 percent, and Austrian pine was 72 percent. While there was a significant effect of bulk density and soil type on percent establishment, closer examination of the interaction of these two factors revealed that for each species only the response at a bulk density of 1.8 $g \cdot cm^{-3}$ on the silt loam was significantly different from the other soil type-bulk density treatment combinations (Fig. 1, upper). Although there appeared to be a tendency for pitch pine to become established more successfully at a bulk density of 1.6 $g \cdot cm^{-3}$ on the silt loam, this relationship was not statistically significant. Similarly, the observed tendency for Austrian pine and Norway spruce to attain optimum establishment at a bulk density of 1.4 $g \cdot cm^{-3}$ was not statistically significant.

Figure 1.—(*upper*) Effect of bulk density and soil type on the establishment of pitch pine, Austrian pine, and Norway spruce seedlings. (*lower*) Effect of bulk density and soil type on the maximum depth of root penetration of pitch pine, Austrian pine, and Norway spruce seedlings. The 95 percent hsd for comparison of bulk density treatment means = 2.415; for the soil type, treatment means = 1.832.



Depth of root penetration

Pitch pine and Austrian pine generally penetrated to a greater depth than Norway spruce on both soil types and at most bulk densities. Average depth of penetration for pitch pine was 7.7 cm, Austrian pine was 7.8 cm, and Norway spruce was 6.9 cm. There was no significant difference between the two pines in their average depth of root penetration.

As with establishment responses, there was a significant interaction between soil type and bulk density in their effect on depth of root penetration (Fig. 1, lower). The silt loam packed to a bulk density of 1.4 $g \cdot cm^{-3}$ markedly reduced the depth of root penetration for all three species. The depth of penetration on the sandy loam was not significantly reduced until a bulk density of 1.6 $g \cdot cm^{-3}$ was reached. Increasing the bulk density of the sandy loam to 1.8 $g \cdot cm^{-3}$ again resulted in a significant reduction in the depth of penetration for all three species. Although there were further reductions in the depth of root penetration on the silt loam at bulk densities above 1.4 $g \cdot cm^{-3}$, the largest reduction was clearly associated with an increase in bulk density from 1.2 to 1.4 $g \cdot cm^{-3}$. Figures 2 and 3 illustrate the effect of increasing bulk density on the growth of Austrian pine on the silt loam and sandy loam soils.

Resistance to penetration

Because soil resistance to penetration (soil strength) was confounded with the two soil types, it could not be formally incorporated in the analysis as an independent variable. Even without statistical analysis, however, the data suggest an additional interpretation of the results of this study.

In Table 2, establishment and root penetration data are arranged by values of resistance to penetration rather than by soil type and bulk density. Establishment appeared to be relatively consistent at resistance to penetration values of 4.7 bar or less. However, increas-

Zisa, Robert P., Howard G. Halverson, and Benjamin B. Stout.
1980. **Establishment and early growth of conifers on compact soils in urban areas.** Northeast. For. Exp. Stn., Broomall, Pa.
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Three northeastern urban coniferous species were able to establish themselves from seed at soil bulk densities up to 1.6 to 1.8 g•cm^{-3}. Root penetration was restricted at a bulk density between 1.4 and 1.6 g•cm^{-3}. Soil type made a significant difference in establishment and root growth.

181.32

Keywords: Soil density, urban trees, regeneration

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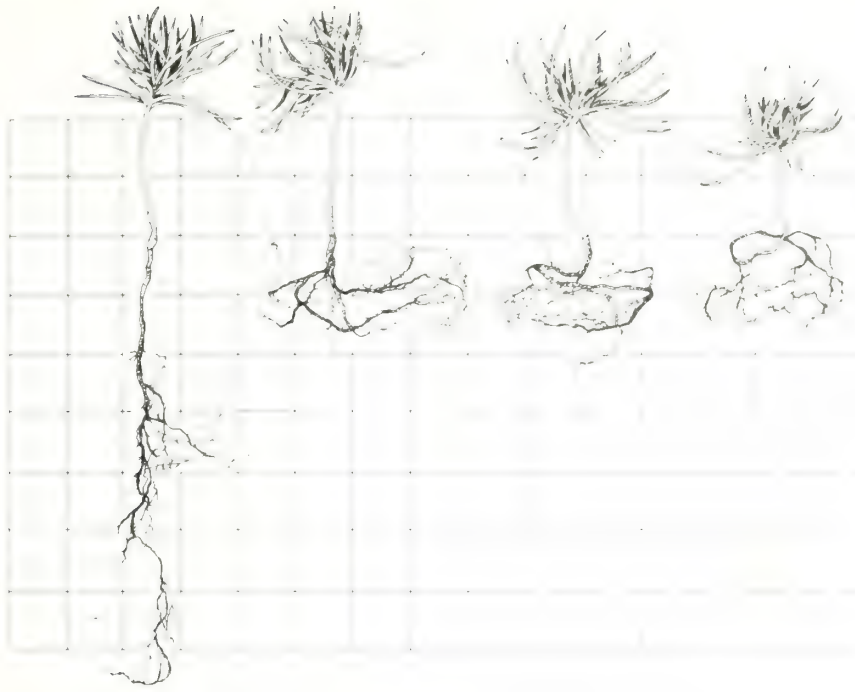

Figure 2.—Effect of bulk density at 1.2, 1.4, 1.6, and 1.8 $g \cdot cm^{-3}$ on Austrian pine seedling growth on a silt loam soil (2 cm grid).

Figure 3.—Effect of bulk density at 1.2, 1.4, 1.6, and 1.8 $g \cdot cm^{-3}$ on Austrian pine seedling growth on sandy loam soil (2 cm grid).

Table 2.—Percent establishment and depth of root penetration of three forest tree species at different soil penetrabilities

Resistance to penetration (bar)	Pitch pine	Austrian pine	Norway spruce
	ESTABLISHMENT *(percent)*		
0.6	92.5	75.0	73.6
1.2	87.5	79.8	87.5
1.4	91.2	76.7	75.0
2.4	90.0	75.0	77.8
2.5	86.2	83.4	91.5
3.7	88.7	76.7	79.1
4.7	87.5	63.3	68.0
9.4	56.3	45.0	53.4
	ROOT PENETRATION *(cm)*		
0.6	15.0	16.0	14.3
1.2	15.0	13.7	13.0
1.4	13.6	15.0	13.8
2.4	7.6	7.7	6.2
2.5	3.9	4.6	2.8
3.7	2.2	2.6	1.6
4.7	2.8	2.5	1.5
9.4	1.4	1.2	1.5

ing the resistance to penetration from 4.7 to 9.4 bar resulted in reduced establishment for all three species. Once established, further root penetration was consistently restricted at values between 1.4 and 2.4 bar or more.

DISCUSSION AND CONCLUSIONS

Our results indicate that several common northeastern tree species may, under certain conditions, be successfully established on compacted soils. Only a bulk density of 1.8 $g \cdot cm^{-3}$ on a silt loam soil significantly reduced establishment. On a sandy loam soil, there was establishment even at a bulk density of 1.8 $g \cdot cm^{-3}$. Root penetration, however, was markedly reduced at a bulk density of 1.4 $g \cdot cm^{-3}$ on the silt loam and at 1.6 $g \cdot cm^{-3}$ on the sandy loam. Consequently, successful germination and establishment does not necessarily mean long-term survival. Trees that become established but develop shallow root systems may be less able to survive periods of moisture stress.

Forristall and Gessel (1955) and Minore et al. (1969) have reported bulk density values critical to the establishment and growth of trees. Pomeroy's (1949) study showed that establishment was poorer on soils with a greater clay fraction, and Foil and Ralston (1967) reported that tree root growth was negatively correlated with bulk density

Although it is difficult to compare the results of other studies due to the differences in experimental conditions, it can be concluded that tree establishment and root growth were generally restricted at soil bulk densities between 1.25 and 1.60 $g \cdot cm^{-3}$. There was some difference among species and only rare success at bulk densities of 1.6 $g \cdot cm^{-3}$. In our study, tree establishment was unaffected by bulk density up to 1.6 or 1.8 $g \cdot cm^{-3}$, depending on the soil. Root growth was restricted at bulk densities of 1.4 or 1.6 $g \cdot cm^{-3}$, as has been reported for western species. Although there was slight indication that pitch pine responded best to the compact soils, large differences between species such as those reported by Minore et al. (1969) and Forristall and Gessel (1955) were not observed.

Although soil bulk density is commonly used as an index of soil compaction, characterizing a compact soil by its resistance to penetration, or some alternate expression of soil strength, may lead to a better understanding of the interaction of a growing root with its soil physical environment. As a growing root penetrates a soil, it displaces and compresses the surrounding soil. The soil resists deformation and the root must develop a pressure to overcome this resistance. Our results showed significantly reduced establishment at resistances greater than 4.7 bar, which suggests that tree roots can penetrate a soil with this resistance during establishment. The rate of root growth is also reduced as soil strength increases (Taylor and Gardner 1963). In our study, root growth decreased significantly when soil strength increased from 1.4 to 2.4 bar.

Three of the most frequently cited explanations for poor root growth in compact soils are: (1) insufficient aeration, (2) soil pores too small for roots to enter, and (3) a critical bulk density exceeded. However, the literature indicates that none of these explanations can fully account for reduced root growth on com-

pacted soils because: (a) roots are unable to penetrate some highly compacted, coarse-textured soils where aeration is adequate, (b) plant roots can enter a nonporous substance if it is not too rigid (Taylor and Gardner 1960), and (c) many studies indicate that critical bulk density values are subject to wide variation because of strong interactions among bulk density, soil type, and moisture content. Results of this study appear to substantiate conclusions (a) and (c).

Additional conclusions can be inferred from the results of this investigation:

- Trees can successfully revegetate urban areas where soil compaction is a significant factor provided soil moisture is readily available.
- Establishment from seed can take place on soils with a bulk density up to 1.8 $g \cdot cm^{-3}$. Root penetration is restricted at lower bulk densities.
- The three species studied seemed to respond similarly to compact soil. The establishment of pitch pine was slightly better than Austrian pine and Norway spruce.
- Soil bulk density, while a valuable aid in interpreting soil conditions, may not be the best indicator of the effects of compact soils on tree establishment and growth.
- A measure of soil strength, such as resistance to penetration, may be a significant variable for determining soil compaction problems. Seedling establishment was uniform on soils where penetrability was less than 4.7 bar, but root penetration was reduced when penetrability exceeded the range of 1.4 to 2.4 bar. Penetrability values vary with soil moisture so these limits may be different at soil moisture tensions other than $\frac{1}{3}$ bar.

ACKNOWLEDGMENT

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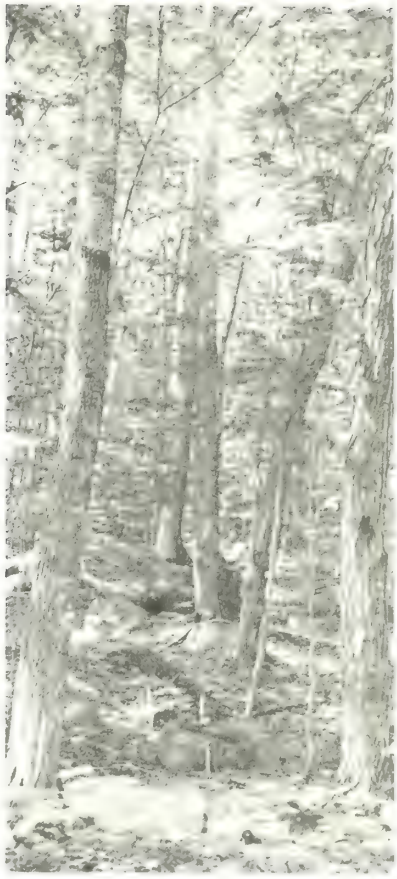

Effects of HABITAT on Stand Productivity in the WHITE MOUNTAINS of New Hampshire

by William B. Leak

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Abstract

Mean annual biomass production of sapling stands was higher on washed tills, which have a hardwood climax, than on habitats having a softwood climax. However, biomass production of pole-timber stands did not differ significantly among habitats. Apparently, differences among habitats in characteristics species composition tends to mask differences in biomass productivity. Demanding species growing on a good site will produce about the same biomass as less demanding species growing on a medium site. Mean diameter growth of sugar maple and yellow birch was much better on fine till and enriched habitats than on the other habitats covered by the study; and preliminary results from older stands indicate that board-foot production is much higher on the better habitats. In conducting intensive silvicultural operations, it is important to favor species well adapted to habitat.

DURING THE LAST FEW YEARS, there has been an appreciable amount of work on land types or habitat classification of New England forests. Ecologic land types are being defined and mapped on the White Mountain and Green Mountain National Forests. These types are defined by correlated features of glacial history or land form, soil materials, and forest vegetation. Supplementary research has shown that species composition of the climax and successional vegetation is related to habitats defined by soil material or type of glacial deposit, and mineralogy (Leak 1978a; 1978b).

However, the relationship of land type or habitat to forest productivity is not clear. Sometimes, land type apparently is indicative of total productivity in volume per acre (Damman 1964). Often, land type is related to the productivity of a particular species such as pine or spruce (Horton and Bedell 1967; Hills and Pierpoint 1960; Mueller-Dombois 1965). Ray's (1956) work indicated that lands with high site index, supporting high proportions of hardwoods, did not necessarily produce the highest volume growth per acre. He found that total volume growth, and volume growth in softwoods, tended to be highest on the poorer sites—those with lower site indexes.

In the White Mountains of New Hampshire, we probably can assume that productivity varies among land types or habitats that are extremely different from one another. High-elevation forests containing stunted trees growing on shallow soils no doubt are much less productive than the taller forests growing on the deeper soils at lower elevations. But productivity differences among lower-elevation forests, which appear potentially suitable for intensive management, are not yet apparent. Past research has shown that certain species, such as sugar maple and white ash, vary appreciably in site index among habitats. But other species, such as red maple, show little consistent change in site index from one habitat to another (Leak 1978a). Available yield information indicates that white pine growing on excessively drained outwash may produce far more volume than hardwoods growing on the best sites. Thus, it seemed quite possible that differences in typical species composition among land types or habitats might minimize differences in productivity.

Because productivity is an important criterion in determining forest land use or management intensity, a study of stand productivity related to habitat was conducted in 1977 through 1979 in areas of granitic drift on the White Mountain National Forest.

METHODS

The general approach was to establish temporary plots in well-stocked, uncut even-aged stands; to carefully age the stands; and then to express stand or species productivity in mean annual growth. Two main series of plots were established: one in sapling stands that averaged about 7 to 14 years of age, the other in poletimber stands that averaged 60 to 70 years.

Thirteen sapling stands were sampled and analyzed. In each stand, eight to ten 54 ft^2 (5 m^2), closely spaced, circular plots were established. On each plot, diameter at breast height (dbh) (if available), height (with a measuring pole), and species of all stems 1 foot tall and taller were recorded. Two trees per stand per species were cut at ground level, and a disc was taken back to the lab for age counts. Because the stands were young, and because sampling was done throughout the growing season, stand ages were estimated to the nearest ¼ year based on (1) sampling date during the growing season, and (2) width of the new or current annual ring. In the midst of each plot cluster, a pit was dug to a depth of about 3 ft and the habitat was classified according to criteria previously described (Leak 1978a) (Fig. 1). Previous re-

Figure 1.—Examples of two habitats in granitic drift. (A) An enriched habitat supporting an abundance of sugar maple sawtimber; (B) A wet compact till supporting a successional stand of red maple and paper birch with some softwoods in the understory.

search indicates that the washed tills, fine till, and enriched habitats have a hardwood climax, while the rock, poorly drained, outwash, wet and dry compact till, and sediment habitats have a softwood climax (Leak 1978a).

Twelve poletimber stands were sampled and analyzed. In each stand, two clusters of four plots each were taken; the two clusters were separated by a distance of up to about 100 feet. Two clusters were used because in these older stands, which have wide-spreading root systems, I wished to make sure that the habitat was uniform over a sizeable area. The four plots within each cluster were 538 ft^2 (50 m^2) closely spaced, circular plots. On each plot, stems 4.5 ft tall or taller were recorded by dbh and species. The largest stem of each species, if a dominant or codominant, was bored at the top of the butt swell (approx. 1 foot above ground) for an age count, and the height was measured with a clinometer. In the middle of each of the two clusters per stand, a pit was dug and the habitat was classified as before. Results from the two clusters per stand (a total of eight plots) were combined into one average in the analysis.

Differences in growth characteristics of sapling and poletimber stands were tested by single-classification analysis of variance, except where data were limited. In making these tests, two habitats sometimes were combined into a single group, e.g., rock and outwash, or fine till and enriched.

In addition to the plots described above, several 10-factor prism plots were taken in stands about 100 years old on the Bartlett Experimental Forest to check on possible differences among habitats in board-foot production. These stands were aged approximately with increment borings; due to varied past histories, these older stands exhibited much more variation in age than the younger pole-

timber and sapling stands. Board-foot volumes, on these prism plots were estimated with local volume tables.

All stands in this study were well stocked with no evident openings in the canopy. Poorly stocked or open areas, which sometimes are on rock habitats or in young stands on wet compact tills, were avoided. The rock habitats were primarily on old streambeds; these have a matrix of rounded rocks in the substrate, sometimes mixed with outwash. None of the rock habitats consisted of very shallow bedrock often encountered at high elevations. All of the stands were at or below 2,000 ft elevation.

BIOMASS ESTIMATION

Because many plots were not accessible by road, and because some of the trees were large in the poletimber stands, biomass was estimated from published regressions and tables. First, comparisons were made of the several available estimators that have potential application to the study area (Goldsmith and Hocker, 1978; Kinerson and Bartholomew, 1977; MacLean and Wein, 1976; Ribe, 1973; Whittaker et al., 1974; Young and Altenberger, 1964; Young and Carpenter, 1967).

In poletimber stands, the Whittaker et al. (1974) equations for aboveground biomass have provided good estimates (a little high) of amounts actually harvested by chipping operations.[1] So we have some confidence in the Whittaker equations for the study area, although their accuracy in sapling stands has not been verified.

I used the Whittaker equations for the poletimber stands, using his red spruce equations for all softwoods and proportionally reducing his sugar maple estimates to calculate the biomass of lower-density hardwoods:

Species	*Specific gravity*	*Proportion*
Sugar maple	.595	1.0
Paper birch	.515	.87
Red maple	.515	.87
White ash	.575	.97
Aspen	.365	.61

[1]Personal communication from J. Hornbeck, Forestry Sciences Laboratory, Durham, N.H.

Dry weights were estimated separately for stems and branch wood plus bark; the total aboveground equations were not used because apparently they contain errors.

For sapling stands, I used the Goldsmith-Hocker (1978) regressions, using separate equations for stems (based on dbh and height) and branches (based on dbh). The Goldsmith-Hocker estimates apparently are more applicable to small trees than the Whittaker estimates.

RESULTS

Species composition

Sapling stands. Species composition of the sapling stands (Table 1) varied appreciably, and was inconsistent with previous research on the relationships of species to habitat (Leak 1978a). Few softwoods were present, even on habitats such as rock, outwash, and wet compact tills where softwoods usually are quite aggressive. The lack of softwoods probably is the result of complete clearcutting, which left little advance regeneration.

Paper birch was quite abundant in all stands except the one growing on the rock habitat. Past research indicates that paper birch may be as common or more common on rock habitats as on any other. Yellow birch was very abundant on outwash; older stands on outwash seldom contain this much yellow birch. The abundance of red maple on the compact tills is reasonable but I would expect red maple to be equally abundant on the rock and outwash habitats. Beech was most abundant on the rock and outwash sites; past research indicates that the washed tills will gradually develop the strongest beech component. Sugar maple was present in noticeable amounts on the wet compact till, however, older stands on this habitat seldom contain much sugar maple. The sapling stands also varied considerably in amounts of pin cherry, striped maple, and other species (chiefly willow and witch hobble).

In general, species composition of the sapling stands appeared to reflect chance events, seed source, or sprouting ability rather than the long-term suitability of species to habitat.

Poletimber stands. Species composition of

Table 1.—Species composition of sapling and poletimber stands, in percent of basal area, and stand characteristics, by habitat of the study areas

Habitat	No. of areas	Mean age	No. stems	Mean dbh	Eastern hemlock	Red spruce	Balsam fir	Paper birch	Yellow birch	Red maple	Aspen	Beech	Sugar maple	White ash	Pin cherry	Striped maple	Other
		years		*inches*							*percent*						
SAPLING STANDS																	
Rock	1	11.5	20,414[a]	.85	—	.6	—	.6	—	5.0	—	53.6	—	—	24.6	15.5	.1
Outwash	2	7.1	43,577	.50	—	.4	—	15.0	42.8	—	.6	30.6	—	—	10.6	—	—
Wet compact till	2	9.6	30,919	.74	—	—	—	15.3	2.2	33.4	8.3	4.0	5.1	1.6	5.4	6.8	17.9
Dry compact till	3	13.7	17,321	1.14	—	1.1	—	12.5	4.3	19.0	.1	10.8	—	—	50.4	—	1.8
Washed till	5	8.4	25,934	.78	—	—	—	36.3	5.1	.6	1.7	21.1	.4	—	27.5	7.3	—
POLETIMBER STANDS																	
Rock	4	69	1,034[b]	5.73	15.9	14.0	5.8	18.7	8.1	15.9	10.5	10.2	—	—	.2	.7	—
Dry compact till	4	62	1,318	4.54	—	—	—	47.6	10.6	23.5	2.0	14.8	.2	—	—	1.1	.2
Washed till	1	64	1,032	4.70	—	—	—	38.3	5.4	23.2	14.2	18.2	.1	—	—	.6	—
Fine till	2	62	607	5.99	—	—	—	—	31.0	4.5	—	4.8	59.7	—	—	—	—
Enriched	1	65	961	5.75	—	—	—	4.1	3.4	16.6	8.5	1.0	55.2	11.2	—	—	—

[a]Stems per acre 1 ft tall or taller.
[b]Stems per acre 4.5 ft tall or taller.

the poletimber stands was much more in line with expectations (Leak 1978a). The rock habitat supported an admixture of softwoods, although these softwoods tended to be concentrated in certain stands. Yellow birch was distributed over all habitats and was most abundant on fine till, a result that was in accord with previous findings. Red maple was moderately abundant on rock, compact tills, and washed tills. Sugar maple was abundant only on fine tills and enriched habitats, a very consistent finding in previous work. And, white ash was abundant only on the enriched sites. Paper birch was more common on rock sites in the poletimber stands than in the saplings, but the proportions still are somewhat variable.

In general, the poletimber stands had developed a species composition that was quite typical of the habitat conditions. The rock habitat supported mixed wood. The dry compact and washed tills supported a beech/red maple/birch association. The fine till had sugar maple/yellow birch (beech usually is a more common component on this habitat). The enriched habitats had sugar maple/ash with miscellaneous other species.

Stand productivity

Sapling stands. Mean biomass production per acre per year was about 25 to 65 percent greater on the washed tills than on the other habitats studied in the sapling stands (Table 2). The washed tills have a hardwood climax (beech primarily) while the other habitats have a softwood climax in areas where the drift is derived from granite. The washed tills have a high proportion of paper birch, which could account for the high biomass production. However, the dry compact till had a very high proportion of pin cherry, which is considered a fast, early producer (Marks 1971); biomass production on this habitat was third highest. Rock, the second highest biomass producer, supported only a moderate amount of pin cherry and a very low proportion of paper birch. It is difficult to see any clear and logical relationships between species composition and biomass production in the sapling stands.

These biomass estimates are similar to Mark's (1971) figures for 4- to 14-year-old

Leak, William B.
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Keywords: Site, soils, habitat type, forest type, growth, biomass.

Table 2.—Mean annual growth in biomass per acre, basal area per acre, dbh, and height, by habitat for sapling and poletimber stands

Habitat	Biomass[a]	Basal area[a]	Dbh[a]	Height[b]
	lb	*ft²*	*in*	*ft*
		SAPLING STANDS		
Rock	3,491	6.49	.07	1.07
Outwash	2,821	6.51	.07	1.10
Wet compact till	2,664	6.01	.08	.84
Dry compact till	2,931	5.66	.08	.75
Washed till	4,398	8.76	.09	1.25
	(*)	(**)	(NS)	(**)
		POLETIMBER STANDS		
Rock	2,129	2.54	.08	.96[c]
Dry compact till	2,263	2.31	.07	1.06
Washed till	2,198	2.31	.07	.94
Fine till	2,162	1.77	.10	1.06
Enriched	2,916	2.67	.09	1.11
	(NS)	(NS)	(*)	(NS)

*Means significant at 0.05 level; **means significant at 0.01 level; NS means not significant.

[a]All stems 4.5 ft tall or taller.

[b]All stems 1 ft tall or taller.

[c]A sample of the largest dominant and codominant trees.

hardwood stands (primarily pin cherry) in New Hampshire which show mean annual aboveground production rates (stems plus branches) of about 3,500 to 4,200 lb per acre. Safford and Filip's (1974) estimates for mixed 4-year-old northern hardwoods are equivalent to about 1,300 lb per acre (stems plus branches). Young's (1967) estimates of mean annual biomass production (stems plus branches) for various hardwood stands in Maine range from about 1,200 to 3,500 lb per acre.

Mean annual basal area and height growth of the sapling stands also varied among habitats in a somewhat similar fashion to biomass production (Table 2). Differences in mean annual diameter growth were not significant, although the trend is toward increasing growth from the rock and outwash habitats to the washed tills. Note the high mean annual basal area growth rates of up to 8.76 ft^2 as compared to the usual rates of about 2 to 3 ft^2 in older stands.

Poletimber stands. In poletimber stands, there were no significant differences in biomass production among habitats (Table 2). The one stand on an enriched habitat had a mean annual biomass production somewhat higher than those of the other habitats; however, examination of this figure as a possible outlier (an observation from another population, Dixon and Massey 1957) did not indicate that it was significantly different. Mean annual diameter growth was about one-third greater on the fine till and enriched habitats than on the other habitats, which indicates that these habitats produce somewhat larger trees although total biomass production is not greater.

Mean annual biomass production tends to be somewhat higher for the sapling stands than the poletimber stands, particularly on the washed tills where biomass production up to sapling size (based on five stands) was about double the production up to poletimber size (based on one stand).

Because diameter growth patterns varied somewhat among habitats, I examined merchantable growth relationships among habitats in the poletimber stands to see whether these differed from trends in biomass production. Based on local volume tables, mean annual growth in cubic feet (4-inch diameter inside bark (dib), top) varied little among habitats; it ranged from about 40 ft^3 per acre on the combined fine till and enriched habitats to about 44 ft^3 on the rock habitats. Mean annual growth in board feet. (Int. ¼-inch rule; trees 11.0 inches and over) in 60- to 65-year-old poletimber stands (ignoring

one older stand on the rock habitat) ranged from 55 board feet on the combined fine till and enriched habitats to about 30 to 35 board feet on the other habitats. This difference reflects the ability of the better sites to produce somewhat larger trees.

The influence of habitat on board-foot production is more evident in the data from a few older stands on the Bartlett Experimental Forest (Table 3). These stands are essentially even-aged, although there is some variation in age distribution and past history. Mean annual board-foot production on the enriched habitat was about 60 percent higher than on the silty sediments; both of these habitats supported well-stocked, nearly pure hardwood stands of 130 to 140 ft^2 of basal area per acre. Mean annual production on the enriched habitat was over two times that found on the dry compact till; this latter stand had 135 ft^2 of basal area. Mean annual board-foot production on the enriched habitat was about 25 and 100 percent better than on the wet compact till and poorly drained habitats, respectively. These latter two stands had somewhat variable age distributions. Both supported a high percentage of softwoods, probably because the cutting that created these stands left a residual understory. Probably the softwood component on these two

Table 3.—Approximate board-foot volume per acre,[a] mean annual board-foot growth, and stand characteristics by habitat for old stands

Habitat	Forest type	Volume	Stand age	Mean annual growth	No. 10-factor prism plots
		fbm	*yr*	*fbm*	
Poorly drained	Spruce-fir	4,760	70[b]	68 (following release)	5
Wet compact till	Mixed wood	11,300	100	113	
Dry compact till	Beech/red maple/birch	5,490	90	61	4
Silty sediments	Beech/red maple/birch	8,747	100	87	5
Enriched	White ash/sugar maple	14,200	100	142	3

[a]Trees over 11.0 inches diameter to an 8.0-inch dib for all species. Approximate figures based on local volume tables, International ¼-inch rule.

[b]Total age of this stand is approximately 115 years; the stand apparently was released about 70 years ago.

Table 4.—Mean annual growth in dbh and height in sapling and poletimber stands, by species and habitat

Habitat	Dbh				Height[a]			
	Sugar maple	Yellow birch	Red maple	Paper birch	Sugar maple	Yellow birch	Red maple	Paper birch
	in				*ft*			
SAPLING STANDS								
Rock	—	—	.08	.04	—	—	1.23	.99
Outwash	—	.07	—	.07	—	1.16	—	1.20
Wet compact till	—	.06	.08	.10	—	.82	1.12	1.54
Dry compact till	—	.07	.06	.10	—	.80	.72	1.36
Washed till	—	.04	.05	.11	—	1.06	.60	1.71
		(NS)	(NS)	(NS)		(NS)	(NS)	(NS)
POLETIMBER STANDS								
Rock	—	.07	.14	.12	—	—	1.05	.97
Dry compact till	.03	.05	.09	.14	—	.88	1.03	1.10
Washed till	—	.03	.09	.13	—	—	.97	.96
Fine till	.11	.11	.12	—	1.11	1.04	.98	—
Enriched	.08	.10	.12	—	1.14	—	1.09	1.09
	(no test)	(	)	(no test)	(	no test		)

[a]Mean height of all stems 1 ft tall or taller in sapling stands; mean height of the largest dominant or codominant stem per species in the poletimber stands.

habitats accounts for the relatively high board-foot production, since softwoods are well adapted to these sites.

Productivity by species

In the sapling stands, there were no significant differences among habitats in mean annual diameter or height growth of any species analyzed (Table 4). Although there appear to be trends—moving in opposing directions—in both diameter and height growth for paper birch and red maple, the trends are not significant because of great variation and overlap in the individual observations.

In the poletimber stands, which represent a greater range in habitat than the sapling stands, mean annual diameter growth of yellow birch was roughly 50 to 100 percent better on the fine tills and enriched habitats than on the other habitats, a result that was highly significant. A similar trend is evident for sugar maple. Differences in diameter growth of red maple among habitats were significant; the rock habitat had higher rates than the fine till and enriched habitat, which in turn, were higher than the dry compact and washed tills. Note that diameter growth of paper birch on rock, dry compact till, and the washed tills was among the highest of any species on any habitat. No tests of height growth in poletimber were made because of limited data; height growth differences tended to parallel differences in diameter growth.

SUMMARY AND DISCUSSION

The main findings of productivity related to habitat were:

1. The relationship of habitat to species composition was clearly reflected in poletimber stands; but species composition varied inconsistently in sapling stands apparently because initial species composition may be caused by many factors other than site. The implications are that species composition may change materially over time when species are reproduced on sites that they are not well adapted to.

2. Mean annual biomass production of sapling stands was significantly better on washed tills (4,398 lb per acre) than on rock, outwash, or compact tills (2,664 to 3,491 lb per acre). Mean annual biomass production of poletimber stands varied from 2,916 lb per acre on one enriched site to between 2,162 and 2,263 lb per acre on fine tills, washed tills, dry compact tills and rock; the differences were not significant although it is possible that additional plots on enriched habitats would substantiate a real difference. In well-stocked stands that do not represent extreme site conditions, demanding species such as sugar maple growing on a good site apparently will produce about as much biomass as less-demanding species (red maple, paper birch, softwoods) growing on less fertile sites. Possibly the differences among habitats in biomass production of sapling stands came about because many of these young stands were undergoing changes in species composition—moving toward associations better adapted to the habitat.

3. Mean annual growth in diameter of poletimber stands was best on enriched habitats and fine tills. The differences were not great, but the results indicate some advantage on the best sites for producing large-size trees. Preliminary plot work in 100-year-old stands indicates that board-foot production is much greater on the better habitats due to the development of large-size trees.

4. Diameter growth patterns in poletimber varied considerably by species. Mean annual diameter growth of yellow birch and sugar maple was much better on enriched habitats and fine tills than on other habitats. Red maple and paper birch, on the other hand, often exhibited good growth rates over a range of habitats. These variable growth patterns help explain why less-demanding species on a mediocre site produce about as much biomass as demanding species on a good site. However, keep in mind that species growth patterns probably are conditioned by competitive effects from other species. It is still quite possible that paper birch, red maple, and softwoods would grow best on the fine tills and enriched habitats if they were free from competitive stress from other species.

The implications are that although long-term production of biomass does not vary greatly over a range of habitats, production

by species will vary considerably. And, the better habitats (fine tills, enriched habitats) tend to produce larger-size trees and higher board-foot growth. In conducting intensive silvicultural operations—including weedings, thinning, prunings, and reproductive efforts—the demanding species such as sugar maple, white ash, and yellow birch should be favored on those habitats where they are well adapted. This seems particularly important when establishing or treating young stands; due to early biological events, these stands may acquire or contain species that are not well suited to habitat over the long run.

Several additional types of productivity research are needed; in particular, the effects of habitat on (1) direct measurements of biomass productivity, which would account for differences among habitats in specific gravity and tree form, (2) the growth responses of managed stands, (3) the productivity of stands of a single species, and (4) the board-foot and quality production of older stands.

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MANPOWER TRAINING in Eastern Forest Industry: a Review and Assessment

by David E. White

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Abstract

Most training in forest industry takes place on the job and is more effective in sawmilling than in logging. Many training programs for woods workers have been ineffective because the rewards of the work are insufficient to attract capable people, leaving the industry to operate in a secondary labor market. Some characteristics of the work and of the technology suggest a need for training of machine operators in the industry, but others do not. An upgrading of pay and working conditions might attract workers of higher quality, thus reducing the need for training. There is a need for training of mechanics and managers, and this need will increase in the future.

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INTRODUCTION

THERE WAS A GROWING INTEREST in manpower training in the forest industries in the 1950's and 1960's. Periodic wood shortages in times of high end-product demand were often viewed as a labor supply problem and gave rise to the "woods labor problem" (Bromley 1957). For many people connected with the industry, the solution seemed to lie in recruitment and training programs, though closer analysis suggested that the labor supply was not the root of the problem (Pikl 1960; Hamilton 1963).

Adding to this interest were public manpower training programs that emerged in the 1960's with objectives, for a time, that seemed to coincide with the goals of forest industry. The Manpower Development and Training Act (MDTA) of 1962 was a public affirmation of the theory that high unemployment rates are the result of structural problems in the labor force and can be remedied by training and retraining workers for skilled jobs in an increasingly technological society. This seemed both the correct analysis and the probable solution to forest industry's labor problem.

By the mid-1960's, the training solution was so well established that the question was not whether to train but who and how to train (Campbell and Power 1966). At this time there also was concern within the forest industry about the effects of mechanization on skill requirements. Mechanization seemed to be taking hold in both the woods and the mills, and its growing importance was subsequently verified by data showing higher rates of capital expenditures per employee and improved man-hour productivity (Bureau of the Census 1975; Bureau of Labor Statistics 1974, 1977; U.S. Price Commission 1972). Projections indicated that these trends would continue if the demand for wood products remained strong (Mooney and Tschetter 1976).

It was widely accepted that capital intensification and technological change had led to, and would continue to lead to, even higher levels of skill requirements in the industry (Granskog and Guttenberg 1973; Bureau of Labor Statistics 1974; Wolf and Nolley 1977). This raised questions about the performance of manpower training programs in the industry over the past two decades and generated concern about the probable need for training in the future.

THE STUDY

The objectives of this study were to (1) review and assess past experience in manpower training for forest industry; and (2) evaluate current and probable future needs for training. The study is limited to blue collar workers in logging and sawmills, and to the eastern half of the United States, though there are several important references to management and supervision and to the labor situation in Canada.

The first part of the report describes past experience with training programs. The second part is a discussion of the demand for training and relies on a conceptual approach to the economics of training as a means of understanding the training problems of the industry.

TRAINING IN THE FOREST INDUSTRY

Training is defined as any investment or activity resulting in the acquisition of a skill (Mincer 1962). Training methods used in industry vary from mere learning by doing, to informal training (unsystematic or systematic on-the-job instruction), to formal training in a classroom. All training methods are interchangeable to some extent; the optimal degree of formal training depends on physical, psychological, and economical factors.

Learning from experience on the part of already qualified workers is excluded from the definition of training because there is no deliberate decision on the part of management or worker, and its cost is unavoidable. Thus, we are concerned with on-the-job training (OJT) and formal training.

On-The-Job Training

The most prevalent means of training in any industry is on-the-job training (Myers 1971). One estimate is that at least 90 percent of all job knowledge in industry is acquired through OJT (Scoville 1969). Apparently, blue collar manufacturing workers believe that OJT is more helpful than other types of training (Piore 1968). And OJT is favored by industrial managers who claim it is essential in acquiring many skills, more effective than other training techniques, and more economical (Piore 1968).

But the prevalence of OJT probably cannot be explained fully by rational criteria. Piore pointed out that training is often an incidental byproduct of what are substitutions of inexperienced for experienced labor introduced to meet production goals—in many cases, management simply does not know how else to train. A more vigorous critic of OJT says the quality of instruction is generally very poor, and that much of OJT consists of "the novice teaching himself to do his job with relatively little assistance and with anticipated results" (Saltzman 1969).

It is apparent that the opportunity for OJT differs substantially between sawmills and logging operations. But there is insufficient information on which to make a general judgment about the quality of OJT in forest industry. Moreover, the quality of OJT is a matter of the attitude of management toward training and a matter of management's ability to design and carry out a training program.

Sawmills

On-the-job training is accomplished more easily in a sawmill than on a logging operation. First, worker activity in a sawmill is concentrated in a single place, making supervision and the establishment of a trainer-trainee relationship easier. Second, a sawmill worker, particularly one at a beginning level, usually works alongside a more experienced worker from whom he can learn. The occupational structure in a sawmill facilitates interjob learning and interjob movement. And third, because of these factors, training in a sawmill does not interfere with production to the extent it does in logging.

An inexperienced worker's first job in a hardwood sawmill is normally that of lumber handler, a job requiring little skill but offering an opportunity to learn from other lumber handlers. Here he can become familiar with the rudiments of lumber grading, a familiarity which is usually requisite to advancement to other jobs in the mill. The next step up the job ladder might be that of machine tailer working behind an edger or linebar resaw, where the worker's responsibility is to divert lumber or waste toward the next processing function. He has a chance to learn the operation of the machine, assist the operator in maintenance and housekeeping chores, and learn techniques of grade and volume recovery, all of which constitutes training for becoming a machine operator.

The two jobs of highest skill in the mill are head sawyer and sawfiler. Even these jobs are likely to be filled by people trained on the job, but in each case the trainees are chosen with greater selectivity and the training is more deliberate and formal. A head sawyer trainee will usually have proven to be a sensible and dependable worker in a number of other operator jobs in the mill. He is given instruction by the head sawyer and will gradually begin sawing for brief periods under the head sawyer's supervision. Sawyer training programs vary from mill to mill but usually require at least a year for the trainee to reach

the minimum acceptable level of skill. Training of a sawfiler is by similar methods and requires at least a year for acceptable proficiency.

Perhaps the greatest problem in training sawmill workers results from a technological change involving new equipment. This is not common since sawmill machinery tends to change only incrementally over time, and worker adaptation usually can be achieved without significant retraining. Where there is a substantial change in technique and equipment, as in the introduction of complex electronic equipment, training often begins with a visit by key sawmill personnel to the plant of the equipment manufacturer. Here the sawmill personnel are given instruction by members of the manufacturer's staff in the installation, operation, and maintenance of the equipment. Whether the new equipment represents technological change or not, manufacturer's representatives usually assist in the installation, "shakedown" operation, and initial training of mill personnel.

There are two skilled occupations in a hardwood sawmill for which OJT is normally supplemented by formal training, dry kiln operators and lumber graders. Training for entry into these positions and for maintaining currency of skills is offered through formal schooling, which will be discussed later.

Logging

Training of workers in logging usually cannot be by an apprentice system because it would be both impractical and unsafe (Hartman 1966). For example, in the felling of timber by chain saw, it would add greatly to the hazards of the job to have a trainee near the cutter and the falling timber. Also, the design of most logging vehicles precludes the presence on the vehicle of anyone but the operator. Safety in logging demands that cutters and operators work individually (Cadenhead 1965).

Because logging is not an "assembly line" operation like milling, the occupational structure does not facilitate interjob learning. And OJT in logging is likely to have a substantial impact on cost by interfering with production.

For all of these reasons, the logging operator places a high value on experience when hiring new employees. Until recently, he could rely on a plentiful supply of rural laborers familiar with woods work by virtue of their farm background, but this is no longer true in many locations (Bond 1972b; Wolf and Nolley 1977). This situation has contributed to the "labor problem" in logging and has resulted in the industry both promoting public programs to train woods workers and hiring workers without experience.

The typical entry job for an inexperienced worker is chokersetter, tallyman, or general helper. From one of these jobs he can observe crew operations and the activities of more skilled workers. Depending on his aptitude, interest, and motivation, he may then progress up the job ladder by bucking logs on the deck and then trying his hand as a cutter; or he may become a wheeled-skidder operator. Working for the typical logging contractor, he will be given no deliberate training; what he learns will be picked up through his own attentiveness and initiative. If he is an employee of a larger company, he may receive instruction in the use and maintenance of equipment in the interest of safety.

The degree of training afforded an inexperienced logging worker depends largely on the attitude and practices of management. Supervisory training in the woods is not easy because operations are dispersed and a supervisor may see any one worker only once or twice a day. However, if management has a concern for safe and efficient operations, appreciates the contributions of training to the success of the operation, and is willing to take the time and incur the cost, the obstacles to supervisory training can be overcome. The following comments are those of an independent logger and sawmill operator in West Virginia.[1] The attitude represented by these remarks is, alas, unusual in the logging industry.

> It has been my experience that labor is just as good as the management it receives . . . to be successful, a logger should be selective in who he hires. After (hiring him) it is your responsibility as manager to train him. After

[1]Unpublished paper presented by O. Blankenship at fall meeting of West Virginia Forests, Inc., Charleston, W. Va., 1977.

you train him to do what you hired him to do, let him learn another job . . . training people is a continuous process on the successful logging job

Formal Training

Formal training is generally defined as training that takes place in an institution or classroom. For our purposes, we include in the definition clinics or workshops where the training is divorced from the production process. Included are programs offered by vocational high schools, postsecondary schools, employing firms and industrial associations, equipment manufacturers, and public forestry agencies. Special attention is given to public manpower programs and their relationship to forest industry.

Vocational high schools

The aim of vocational education is to provide young people with the fundamentals of specific occupations and to prepare them to acquire additional skills more readily either on the job or through additional schooling (National Manpower Council 1954). Over the past several decades, vocational education has secured an established place in our system of secondary education despite strong opposition within and outside the field of education. Those who support it claim that vocational education is necessary to prepare for "real life" the large proportion of students who do not choose to go on to college. It provides students with an easier transition from school to the workaday world and allows them to enter the labor market at a higher wage than they would otherwise receive. Thus, it is claimed that vocational education is beneficial to the student, to industry, and to the community (Stormsdorfer 1972; National Manpower Council 1954).

Opponents of vocational education argue that it is too narrow, often preparing students for specific jobs or specific employers rather than providing them with a broad base for further training. A second criticism is that vocational education is ascriptive and steers less able or poorly motivated students, at a very early age, into lower status occupations on the grounds that they are not capable of more demanding or more prestigious work. A third criticism is that vocational education "waters down" the curriculum to the point where students do not master the mental skills they are capable of acquiring. Finally, it is said that vocational education compels students to follow study programs that reduce their opportunity of going on to college if they wish to do so (U.S. News and World Report 1976; National Manpower Council 1954; Reubens 1976). The critics of vocational education emphasize the importance of a broad-based secondary education and argue that training for specific jobs should take place on the job (Mansfield 1968).

Perhaps the most strident contemporary criticism of vocational education is that by James O'Toole (1977). O'Toole argues that vocational education rests on four erroneous assumptions: that teenage unemployment can be attributed to a shortage of skills; that technological change is creating a labor market with increasingly high skill demands; that vocational education works; and that employers demand school graduates with specific skills. O'Toole says that what employers really mean when they talk about a shortage of skills is the absence of blue collar virtues, or the willingness to tolerate undesirable jobs. Regardless of whether one accepts O'Toole's arguments, they penetrate to the core of some of the issues important to this study and are worth keeping in mind as we proceed.

Vocational education programs in forestry and wood harvesting first came on the scene in the 1960's in the southeastern United States. They resulted from several factors, including a fear of labor shortages in the pulpwood industry, high youth unemployment that prompted expansion of Federal assistance for vocational education, and a decline in the number of farms and farmers that led the agricultural education establishment to expand its horizons beyond traditional agriculture.

With the aid of the American Pulpwood Association, state education departments and vocational education teachers developed courses that would give students the competence required for beginning jobs in timber harvesting. On the average, these programs consisted of 5 hours of study per week during

the senior year, with course content highly variable and dependent on the background and interests of the teacher. Programs eventually were established in the North, especially the State of Maine, and the Northwest, but reached the highest development in the Southeast. There, industry-school board advisory committees were established in each state and special courses for teachers have been supported by industry.

Evaluation of these programs is difficult, and this is true apparently of vocational education programs in general (Reubens 1976). Formal evaluations have never been made by participants, perhaps because program goals never seemed to be spelled out. A review of available information leads one to the conclusion that the principal objectives of these programs have been recruitment (or placement) of labor rather than the imparting of salable skills, and that even in this respect industry backers have not judged the programs to be successful. One observer believed that these programs offered "the best means of attracting intelligent and ambitious young men to choose a career in logging" (Glascock 1965); others were less sanguine after seeing a few years' results. The following quotation is from a 1970 memorandum written by an industry representative and circulated by the Department of Public Instruction of the State of North Carolina:

> Because of the very nature of the pulpwood business, we have sometimes questioned the value of these high school courses in accomplishing their primary goal—that of providing new, young blood in the pulpwood business. There have been times when we felt that its secondary aim—that of improved public relations—was the main value of the course.

Some obvious public policy questions arise here, the answers to which may not be forthcoming without one becoming embroiled in the vocational education controversy already discussed. Should high schools train young people for work as specific as pulpwood logging? Should public funds and facilities be used to provide "young blood to the pulpwood business," or to further the public relations of the industry? Further, participation in these programs by the large pulp and paper companies in the South may be subject to question because the companies, as a rule, rely on small logging contractors for most of their wood and, therefore, have not offered employment to vocationally trained loggers.[2]

The success or lack of success of these programs was revealed in a 1977 survey by the American Pulpwood Association (APA) (McKnight 1977) which showed that 44 participating schools in the Southeast had graduated about 3,250 students who had taken the course, of whom about 340 were employed in some way in logging operations. An APA survey of four schools in Maine and one in Vermont revealed a higher percentage of placement, with 90 of 247 graduates employed in forestry or timber harvesting (unpublished material supplied by the APA). In any case, the programs in neither area have been in existence very long (an average of 6 years in the Southeast, 4.5 in the Northeast), and the data may not be meaningful.

Postsecondary schools

Postsecondary vocational training has been subjected to many of the same criticisms, and defended by the same arguments, as high school programs. One study found postsecondary programs to be not greatly superior to high school training (O'Toole 1977). Yet such programs have increased rapidly in number in recent years. The "1975-76 Directory of Postsecondary Schools with Occupational Programs" (National Center for Education Statistics 1977) lists nearly 12,000 schools, over 100 of which offer instruction in the forest technologies. While many of these schools include instruction in wood harvesting and utilization, the majority offer a broad-based curriculum in forestry and gear the programs to the technician level. Only two schools in the East are known to specialize in training for entry level positions in wood harvesting; the following discussion is confined to these two programs.

The forest harvesting technology program at the Duluth (Minn.) Area Vocational-

[2]This situation seems to be changing as a result of changing industry structure. There is further discussion of industry structure in the section on labor market characteristics.

Technical Institute was established in 1969, reportedly at the suggestion of an industrial association and for the purpose of providing a skilled labor pool for the forest industry (Timber Producers Bulletin 1971). The program has one class per year of 46 weeks duration and enrolls about 30 students. Training is given in equipment operation and maintenance, hydraulics, welding, gas and diesel engine maintenance, accounting, job layout, scaling, surveying, and other related subjects. Of the 58 "competencies" required of each graduate, only 11 can be said to be related solely to wood harvesting, while 47 are of a general nature and widely applicable in industry.

The director of the program reported in January 1978 (personal correspondence with Mr. Jerry Back), that the total number of graduates to date was 125, that this represented 85 percent of those who had entered, and that 60 percent of the graduates went directly into woods work, 30 percent into closely related areas such as trucking and equipment mechanics, and 10 percent into unrelated employment.

The wood harvesting technology program at Washington County Vocational-Technical Institute at Calais, Maine, is similar to the one in Duluth but is more closely geared to specific woods skills (Krug 1975). Established in 1972, again at the urging and with the cooperation of forest industry, the program lasts 22 weeks. Overlapping of classes allows completion of six classes per year. Each class numbers about 15 to 18, with an attrition rate of 15 to 20 percent.

The primary objective of the program is to turn out cutters and skidder operators for the local pulp and paper companies; hence 55 percent of the instruction is in chain saw and skidder operations and 25 percent in maintenance. The school has an active recruiting program and attracts students from several Northeastern states. The number of applicants about equals the spaces available, with about one-third of the students attending on grants from the Comprehensive Employment Training Act (CETA). The director would like to be more selective in admitting candidates but the number of applications has not allowed this (personal interview with Mr. Joe Krug 1977), and no selectivity is possible with CETA-supported students. Approximately 70 percent of the graduates find work in the woods or in related employment.

The two schools have other similarities. Each has earned a good reputation among employers. They both rely on informal feedback from employers as the only means of program evaluation. They depend on industry support not only for placement of graduates but also for donations of equipment. Neither program requires a high school diploma for admission. Both have low student-teacher ratios and a high cost per student. At Washington County, the average cost per student in 1977 was about $5,000. This is in contrast to an average cost of less than $2,000 for the institution as a whole. Students at both schools pay tuition ($450 at Duluth and $1,000 at Washington County), and buy their own books, clothing, boots, etc.

Both of these schools are to be considered successful if judged on the basis of meeting stated objectives. Several factors have contributed to this success: the training provides a reasonably thorough familiarization with equipment, processes, and basic mechanical principles; the large financial investment in the program results in adequate facilities, equipment and qualified—almost personalized—instruction; most of the students share the cost of the training and, therefore, enter with serious intent and a motivation to make the investment pay off; finally, the schools are located in areas of relatively intense wood industry activity and maintain close relationships with potential employers.

This is not to say that these schools necessarily represent a wise use of public funds. Some of the same questions raised in connection with high school vocational programs are applicable here. For example, it is legitimate to ask whether a $4,000 net investment per student to train a worker for entry level employment in woods work is a justifiable public expenditure. But it might be shortsighted to regard these programs as wasteful or as mere subsidies to the forest industry. In areas where forest industry constitutes a major segment of economic activity, and where employing firms are large, pay average or better than average wages (as in Maine) and offer oppor-

tunity for advancement, it may be socially, economically, and politically astute to allocate public funds for the upgrading of human capital in that industry.

Nor can the criticism of early ascription that is leveled at high school vocationalism legitimately be applied to these postsecondary schools. The latter are outside the stream of basic education, the students who attend are more mature (some are in their mid-30's), and they have made a conscious decision to apply themselves in a special field at least partly at their own expense.

Industry training

Formal training programs are rare in the forest industry, and most of those that have been undertaken have been unsuccessful (Bond 1972b; Swan 1969). The reasons for the uncommonness of formal industry-supported training will be dealt with in detail in the section on demand. Suffice it to say that such programs have not been considered as needed except in unusual situations. The reasons for the lack of success of programs that have been attempted are low capability and poor motivation of trainees; disillusionment of trainees with working conditions, length of the work year, and pay, leading to high quit rates; and ineffective training methods (Deabay 1975; Ballantyne 1975; Bond 1972c; Thibodeau 1965).

In logging, formal training programs have been instituted to recruit employees in areas of labor shortage. This is the case in Maine, where manpower needs are high among the large forest industry companies operating in relatively remote areas. The manpower situation in Maine has been complicated by the tradition of using Canadian bonded labor and the political pressures to end this practice that have arisen during periods of high unemployment in the domestic labor force (Bond and Wolf 1978; Falk 1977). The threat of loss of bonded Canadian labor has prompted pulp and paper companies in Maine into repeated attempts to establish woods labor training programs.

The Great Northern Paper Company, for example, made four attempts to develop recruitment and training programs from 1950 to 1965, all of them unsuccessful (Thibodeau 1965). The reasons for these failures seem to have been the very same as those that made woods work unattractive in the first place; that is, hard manual labor, exposure to the elements, a short work year that limited income, and the poor public image of such an occupation.

It was not until the 1970's that company training programs in Maine began to show some success, with a relatively large proportion—Great Northern reports 75 to 80 percent—of the trainees going on to become productive woods workers. A number of factors have contributed to this turnabout. Mechanization of operations has reduced the physical hardships of the work, raised productivity and wages, and improved the self-image of the worker. Also, the companies have learned a great deal from previous experience and have upgraded the programs and placed them under the direction of professional personnel training specialists with sizeable budgets.

Current programs of the Great Northern Paper Company are conducted with careful attention to trainee selection. Most trainees are high school graduates and are attracted from other jobs rather than from the ranks of the unemployed. Program content and transition from training status to regular work are other areas that have been improved (Deabay 1975). The success of Great Northern's conventional woods training program, which lasts 10 weeks, has led the company to establish a second program of 6 weeks for equipment operators. Currently, all new woods employees are required to be certified through participation in one of these programs.

The training director at Great Northern reports that the cost per trainee is $2,500 in the conventional program and $3,000 in the mechanized program (personal interview with Mr. Dana Saucier, 1977). Quite obviously, such costs of training can be borne only by the larger firms that depend on company crews for a large share of their wood, and would be incurred only in situations where the woods labor supply is otherwise so precarious as to threaten pulpwood supplies and the continuous operation of the mill.

But formal training programs such as those in Maine have generally not been necessary in other parts of the Eastern United States

despite the fact that essentially the same skills are required of woods workers.[3] This points up the special nature of the labor supply for timber harvesting in Maine and the difference in the structure of the industry there compared with that in other areas.

Public manpower training programs

During the 1960's, forest industry firms and associations participated in several training programs supported by Federal funds under the Manpower Development and Training Act. Most of the early (1960's) and unsuccessful industry training programs were undertaken with the assistance of MDTA funding (Swan 1969). A brief review of the short history of MDTA will be helpful to show that the goals of this program and those of forest industry came to a parting early on.

The MDTA had its origins in the automation scare that emerged in the 1950's. A key assumption on which MDTA rested was that a large number of jobs were awaiting workers with deficient or obsolete skills if only the workers could be trained or retrained to qualify for them. This is the so-called structural theory of unemployment, and to those who accepted it, the objectives of MDTA seemed to compliment the labor recruiting objectives of forest industry—or to almost any industry, for that matter.

Benefit cost analyses of early MDTA training efforts were favorable (Borus 1964; Stormsdorfer 1968), but these analyses reflected certain biases that were built into the programs and that tended to ensure success (Sewell 1971). The principal objective was to bring about a reduction in unemployment, and this led program administrators to choose the best educated and most competent individuals.

Not long after its inception, however, the original employment objectives of MDTA gave way to the broader objectives of the "antipoverty" program, and it was clear that MDTA was not reaching the "hard core" unemployed or the "disadvantaged." These shortcomings were remedied through a series of amendments to the original Act so that by 1968, 65 percent of the participants were considered disadvantaged (inexperienced youth, members of minorities, persons with limited education, the rural poor, and older workers).

As program objectives shifted from reducing unemployment to increasing the income of the disadvantaged, evaluations were less favorable (Main 1968; Somers 1968), and the mutuality of goals between MDTA and industry vanished. The objectives of MDTA in recruitment had become markedly dissimilar to those that would serve the forest industry's purposes, but the industry at that time was still in the process of learning its lesson that the success of any training program depends largely on the quality of the individuals selected for training (Perry et al. 1976).

The MDTA program in forest industry for which the most complete record is available is the Northeastern Regional Logger's School. This school was begun in May 1968, and was sponsored by the State of New Hampshire with the assistance of industry. Its objective was "alleviating the dependence of the logging industry on Canadian labor." An industry committee that evaluated the school in January 1969 (APA 1969), gave the school good marks on the thoroughness of its recruiting effort and its training techniques, but suggested that the screening of potential trainees should be improved to "determine whether the prospect really wants woods work."

That some of the trainees did not really want woods work is evident in the enrollment data. Of the 160 trainees referred to the school through January 1969, 73 had dropped out, 63 had graduated, and 24 were still in the program. Soon thereafter, the school was discontinued because of the termination of Federal assistance under MDTA. During its first 9½ months of operation, the school trained "less than 100 men," with placement "probably in the 35 to 40 percent of graduates

[3]This is not to say that other companies do not have effective training programs for their employees. Firms such as WESTVACO, Inland Container, and Weyerhaeuser have developed good OJT programs in the Appalachian Region. However, most large forest products companies in the East obtain only a small fraction of their wood by the use of company employees, and contractor employees do not have access to company training programs. The large companies in Maine are different because they do most of their own logging.

range." One official closely associated with the school attributed its placement problems to geography: the school was in New Hampshire but the most likely employers were in northern Maine. The total cost of the school was $239,000 or about $6,000 to $7,000 per graduate placed in woods work. These are 1969 dollars and are to be contrasted to the $2,500 to $3,000 cost per trainee that Great Northern Paper Company reported in 1977.

Public manpower programs to train loggers in Canada have achieved similar results and have been better documented. An evaluation by the Forest Engineering Research Institute of Canada (Scott and Cottell 1976) revealed high attrition rates among training graduates. Programs in Canada were sponsored either by industry or directly by Canada Manpower. Industry data showed that only 43 percent of the graduates were retained in forest industry for 1 year. Canada Manpower results were worse, showing only 29 percent of graduates employed in forest industry 3 to 4 months after completing training. These high attrition rates were blamed on improper selection of trainees and insufficient attention to the placement of graduates. Significantly, the authors say: "However, training programs should not be held responsible for turnover of new workers that is attributable to poor job or community conditions, or to better economic opportunities. Solutions to these problems lie elsewhere" (Scott and Cottell 1976, p. 52).

Training by equipment manufacturers

Training for operators of newly purchased equipment has already been discussed under the subject of OJT. But some equipment manufacturers, particularly those that make modern, complex logging machines, offer formal classroom training for mechanics employed by customer firms. When these programs were initiated, they usually consisted of several days of classroom study emphasizing the theory of the electronic circuitry, and depended on the experience of the mechanic to enable him to make the required application to the hardware. However, with the increasing complexity of the machines and the lack of sophisticated knowledge among customers' mechanics, the training was made more comprehensive and longer, up to 2 months in one case (Willows 1976).

Training of operators is a matter of concern to machinery manufacturers because a machine's performance depends on the competence of the operator. Most manufacturers have participated in training programs such as those already discussed, usually with disappointing results. In their view, one of the chief obstacles to training is the high rate of turnover, not only among customer's machine operators, but also among their own technical sales people. As a result, the extent of operator training offered by most manufacturers is limited to the salesman or serviceman spending an hour with the operator at the time of delivery.

Not surprisingly, logging managers have a low opinion of the training services available from manufacturers. Experience has shown loggers that the training of both mechanics and operators is one of trial and error, and the result is low production and high costs until the required experience is gained to operate the equipment within its capacity and reduce downtime to an acceptable level.[4]

Programs of public forestry agencies

Public forestry agencies such as the USDA Forest Service, state extension services, and state forestry agencies offer on an irregular basis training programs in some of the technical aspects of logging and lumber processing. These agencies often work in cooperation with industry associations or individual firms, and the sessions are usually 1 to 3 days long. In timber harvesting, the most common subjects are log grading and logging road construction, while courses in dry kiln operation and lumber grading are commonly offered to lumber producers.

In 1973, the Forest Service commissioned an evaluation of its Forest Products Utilization (FPU) Program, and because the FPU Program is representative of all efforts in this field, the evaluation is worthy of mention. The

[4]Parker, E. Operating whole tree chipping systems. Unpublished report. WESTVACO, Covington, Va. 8 p.

frequent use of generalizations and the lack of rigor in the evaluation report (Greenacres Consulting Corporation 1973) illustrate the difficulties of assessing the effectiveness of an education program, but one passage from the report seems noteworthy.

> FPU staffers across the Nation have contributed to or participated in (as instructors) numerous group training sessions ranging from lumber grading classes for an individual company through log bucking to grade sessions for the total membership of a particular trade association. . . . The results have been as varied as the topics treated. Some classes, e.g., the dry kiln operators courses, have been most valuable and many unsolicited testimonials to their value can be found in FPU files. Other classes have been complete failures, having been attended only by individuals affiliated with the FPU program or having been cancelled for a lack of interest.

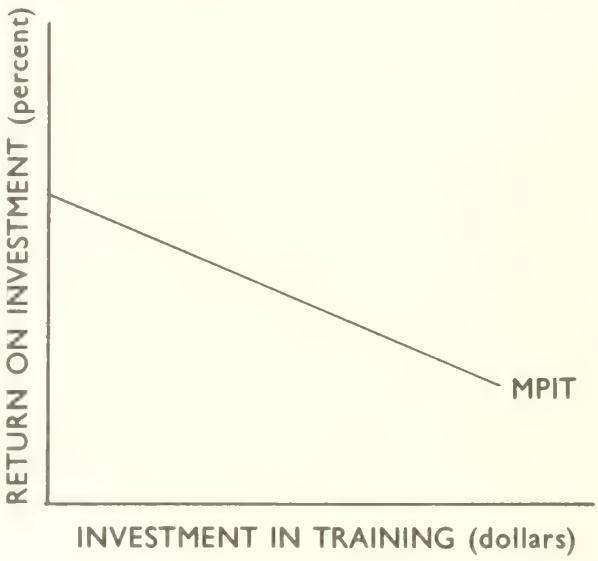
One area of great potential contribution to the forest industry not being filled by public agencies is training in management. Logging and sawmill operators and managers are often weak in management sciences and personnel relations (Latham and Kinne 1971; White 1965); yet the educational efforts of public agencies tend to avoid these subjects and concentrate on technical processes and marketing. But it is possible that training in management could, in the long run, have a greater impact on efficient utilization of both the timber resource and manpower. Two difficulties are apparent here, however. One is that public agency personnel usually are not knowledgeable in this area and would have to bring in other specialists. The other difficulty is that managers in the industry who are in greatest need for such training might not be willing to participate.

THE DEMAND FOR TRAINING IN FOREST INDUSTRY

We turn now from a descriptive to a conceptual treatment of the subject to better understand the problems associated with training in forest industry and to get a glimpse of what the future might hold. The tool used is demand analysis.

The demand for training in an industry can be viewed as a schedule of the anticipated returns on investment in training activities. In Figure 1, a line representing the marginal productivity of investment in training (MPIT) results from the relationship of various levels of investment in training (horizontal axis) and the expected rate of return on that investment (vertical axis). Successive levels of investment are subject to diminishing rates of return. The model is applicable to an industry, a firm, or even an individual. Here we will make use of it in analyzing those factors that influence forest industry firms in their decisions about whether to invest in training.

Figure 1.—Marginal productivity of investment in training.



To complete the model there must be, of course, a standard against which training investments can be judged, and for this purpose we will use a constant internal rate of return (IRR). Managers will invest in training only if the MPIT as they perceive it exceeds the IRR. In Figure 2, for example, investment in training beyond point (i′) would be unattractive if the internal rate of return was at IRR_1, and a much lower level of investment (i′) would be called for if IRR_2 prevailed.

No manager considers his training needs or opportunities in such a formal and abstract

White, David E.
1980. **Manpower training in eastern forest industry: A review and assessment.** Northeast. For. Exp. Stn., Broomall, Pa.
20 p., illus. (USDA For. Serv. Res. Pap. NE-453)

Most training in forest industry takes place on the job and is more effective in sawmilling than in logging. Many training programs for woods workers have been ineffective because the rewards of the work are insufficient to attract capable people, leaving the industry to operate in a secondary labor market. Some characteristics of the work and of the technology suggest a need for training of machine operators in the industry, but others do not. An upgrading of pay and working conditions might attract workers of higher quality, thus reducing the need for training. There is a need for training of mechanics and managers, and this need will increase in the future.

945.3

Keywords: Labor training, woods labor, sawmill labor, labor supply, mechanization

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Figure 2.—Comparison of investment in training with alternative investment within the firm.

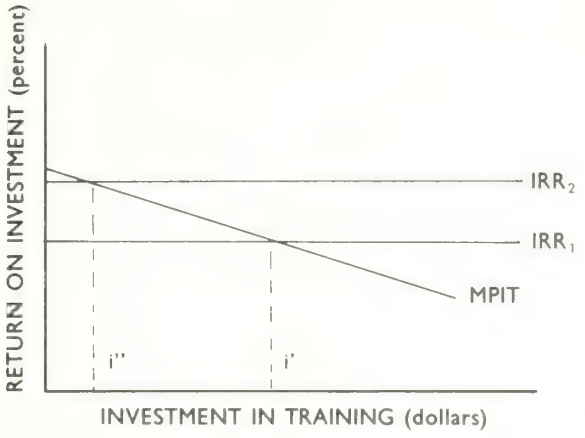
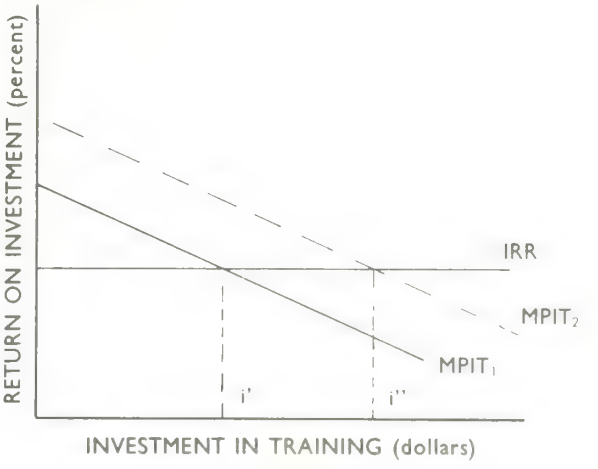


Figure 3.—The effect of factors that increase the need for training on MPIT and investment in training.



manner. Nevertheless, he is not likely to undertake a training program unless he thinks it will be profitable, and this device can be helpful in identifying the factors that are relevant to his decision and what sort of influence those factors have. Each circumstance in a firm or industry that tends to increase the need for training tends to raise the MPIT (Fig. 3). Conversely, any circumstance that decreases the need or desirability of training tends to depress the MPIT. In the discussion that follows, all of these factors have been grouped under three headings: occupational characteristics, the rate of technological change, and labor market characteristics.

Occupational characteristics

The *level of skill required for entry* is an important determinant of the need for training. The higher the skill required on beginning jobs, the greater the incentive to provide training for new and inexperienced workers. As was pointed out in the earlier description of job ladders in logging and sawmilling, and as other observers have noted (Bond 1972b; Cottell 1972), most firms in the industry have entry level jobs that require little skill, so there is little incentive for management to undertake preemployment or vestibule training. Exceptions may be where there is a labor supply problem and the training program serves as both a recruiting device and a means of placing new employees in high-productivity jobs in a short time, as was true in the case of the Great Northern Paper Company.

A second occupational characteristic that affects the productivity of investment in training is the *opportunity for interjob learning.* Such opportunities are not readily available in timber harvesting; thus the influence of this factor is to raise the MPIT in harvesting operations. In sawmilling, however, the concentration of workers in a continuous production line has the opposite effect.

The *degree of supervision* that is possible is a third factor, and here the situation is similar to that of interjob learning. Supervision is difficult on a logging operation and relatively easy in a sawmill, thus tending to raise the MPIT in logging and reducing it in milling.

A fourth consideration is the *range of skills required.* Some logging operators, particularly the smaller ones, need to have each of their crew members familiar with a number of different jobs—perhaps even all of the jobs in the operation. This increases the crew's flexibility and prevents shutdowns when a crew member is absent. The same holds true in small sawmills, and the effect is to raise the MPIT in both logging operations and sawmills of small size. This factor is likely to be less important in large firms where more than one employee is available for any one occupation slot.

The fifth occupational factor is the *degree*

of danger present on the job and the importance of safety. Both logging and sawmilling are among the most hazardous of industries and incur high costs in the form of workmen's compensation insurance. There is ample incentive in both industries for investment in training for the safe use of equipment.

The final occupational characteristic that influences the MPIT in forest industry, and perhaps the most important one, is the *similarity of skills from firm to firm.* Becker's (1964) theory of general and specific investments in human capital is instructive here. *General* training results in skills that are useful not only to the employing firm but also to its competitors. *Specific* training is useful only to the employing firm. After completion of training, a specifically trained worker is attached to the employing firm if he wishes to make use of his skill, while a generally trained worker can "sell" his skill elsewhere. Since the technology of both logging and milling is similar among firms in each of the industries, training in both industries is general in nature.

Under such circumstances, a firm will not undertake training unless its cost is borne by someone else; that is, by the employee or the public. If it is to be the employee who pays, the "payment" will ordinarily be acceptance of a wage lower than that of the fully trained worker while having the same or nearly the same work responsibilities. To put this in terms of the marginal productivity theory of wages, the worker's "wage" must cover his contribution to production and the cost of his training, leaving his actual wage at a lower level until he is fully trained.

The generality of skills and training in the forest industry is a distinct disincentive for employers to incur training costs (Bond 1972b). The theory of general versus specific training also helps explain why pulp and paper companies in Maine are willing to train woods workers while companies elsewhere are not. The geographic isolation of the Maine companies and the lack of alternative employers serve to make the training specific rather than general because the trainees have limited opportunity to transfer the skill to another employer unless they are willing to relocate.[5]

The effect of all six occupational characteristics is summarized in Table 1. It is evident that in logging, these occupational characteristics present both incentives and disincentives for investment in training, while in sawmilling there is a predominance of disincentives.

The rate of technological change

It is a common assumption that technological change raises the level of skills required and leads to the need for training. The reasoning is that mechanization results in the introduction of machinery of greater complexity, that workers manning and servicing this machinery need higher types of skills, and that, therefore, employers see an upward shift in the MPIT. This has been the widespread view in the forest industry over the past decade as mechanization and capital-labor ratios have increased (Bureau of Labor Statistics 1974; Jaakko-Poyry Company 1975).

[5]The training program of Great Northern seems to be one in which the company and the trainee share the cost of training. The trainee receives a wage that is roughly two-thirds of that paid to a "Class A" or experienced worker. After the training period, he becomes first a "Class C" and then a "Class B" worker before reaching "Class A" status about 6 months after training. At each succeeding class level, he receives a higher wage.

Table 1.—The positive (+) and negative (−) effects of occupational characteristics on the productivity of investment in training

Occupational characteristics	Logging		Sawmilling	
	Small firm	Large firm	Small firm	Large firm
Entry level skill required	−	−	−	−
Opportunity for interjob learning	+	+	−	−
Degree of supervision possible	+	+	−	−
Range of skills required	+	−	+	−
Degree of hazard	+	+	+	+
General vs. specific skills	−	−	−	−

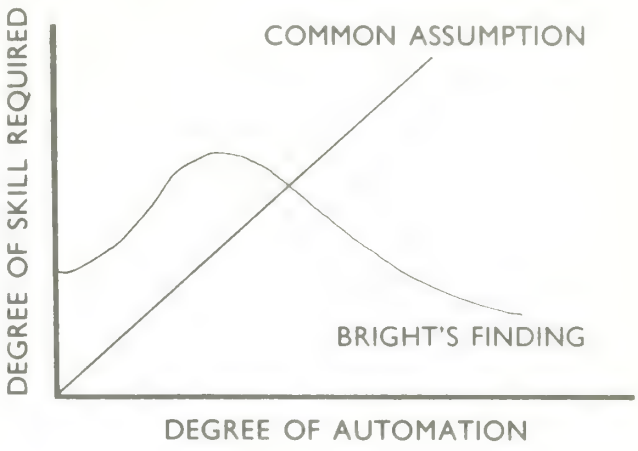
But there has been some important research that questions the validity of the assumed relationship between technological change and skill requirements. On the basis of studies in a number of industries, James Bright concluded that the upgrading effect of automation has been greatly exaggerated (Bright 1966). "On the contrary," says Bright, "there was more evidence that automation has reduced the skill requirements of the operating work force."

Bright was not the first to advance the idea that automation reduced skill requirements. Veblen (1958) wrote about it in 1904. In 1954, the National Manpower Council reported that employers were convinced that specific skills were not of paramount importance because the highly skilled, multioperation jobs in industry were being reduced to a series of simpler jobs that could be handled by workers of lesser skill (National Manpower Council 1954).

But Bright was the first to do empirical research on the subject. His analysis showed that many types of automated machinery require less operator skill after certain levels of mechanization are achieved, and that many jobs formerly requiring long experience and training are reduced to easily learned, machine-tending jobs as a result of automation.[6] In Figure 4, Bright's conclusion about the relationship between automation and skill demands is compared with the common assumption.

One suggestion that comes from Bright's work is that the degree to which mechanization in the forest industry affects skill requirements can be determined only by investigating each job and the degree to which it is altered by increasing the sophistication of machinery. Constraints on resources limit us to a much more modest approach here. Three recent changes in the technology of both logging and milling are assessed in terms of their effect on skill requirements. These changes are: in logging (1) natural spar tree to portable steel tower, (2) chain saw to tree shear, and (3) wheeled skidder and piece loader to whole tree yarder and chipper; and in milling (1) band or circular saw to chipping headrig, (2) manual to automatic sorter and stacker, and (3) manual to automatic trimmer. All of these changes have been cited as mechanical improvements that have increased man-hour productivity in recent years.

Figure 4.—The relationship between automation and degree of worker skill required.



Bright sharpened the definition of a "skilled worker" by examining the demands machinery makes on the worker. He drew up a list of 12 categories of contributions for which the worker receives compensation. Eleven of Bright's categories are used here; the twelfth (seniority) seemed inapplicable to this analysis. A judgment on the effect of each technological change on each worker contribution was made on the basis of a consensus of a group of faculty members in the Division of Forestry at West Virginia University. The results of the assessment are shown in Table 2. Each letter L, S, or H means that the technological change was judged as resulting in a lower, the same, or a higher worker contribution, respectively.

The arbitrariness with which the judgments were made precludes the drawing of any firm conclusions. But on the basis of some of the recent and important technological changes in the industry, it seems that the process of

[6]Bright draws no distinction between automation and mechanization. Ordinarily, mechanization is defined as the process wherein machinery takes the place of human or animal effort, and automation is the latter stage of mechanization where control of the machinery becomes increasingly automatic.

Table 2.—Changing contribution of workers with changing technology in logging and sawmilling[a]

Worker contribution[b] or sacrifice traditionally receiving compensation	Logging			Sawmilling		
	Natural spar tree to portable steel spar	Chain saw to tree shear	Wheeled skidder and piece loader to whole-tree yarder and chipper	Band or circular saw to chipping headrig	Manual to automated sorter and stacker	Manual to automated trimmer
Physical effort	L	L	L	L	L	L
Mental effort	S	H	L	L	S	S
Dexterity	L	L	S	L	L	L
General skill	L	H	S	S	S	S
Education	H	H	S	S	S	S
Experience	H	H	L	S	L	S
Exposure to hazards	L	L	L	S	S	S
Acceptance of undesirable job conditions	L	L	L	S	S	S
Responsibility[c]	S	H	H	L	H	S
Decisionmaking	L	H	L	L	L	S
Influence on productivity	H	H	H	S	H	H

[a] L = Lower; S = Same; H = Higher.
[b] Refers to operators and helpers but not to mechanics, engineers, or supervisors.
[c] Safety of equipment, of the product, of other people.

mechanization in logging has placed heavier demands on a number of worker contributions that might be included in a definition of skill. Note, however, that the most recent of the technological changes, the switch from wheeled skidders and loaders to whole-tree yarding and chipping, is judged as requiring greater worker contribution in only 2 of the 11 categories. Relating the logging portion of Table 2 to Bright's curve in Figure 3, it seems that while logging is still at an early and high point on the evolutionary curve of mechanization and skill demands, it may have reached the apex of the curve so that future technological change will not require greater skill among workers.

In contrast to the analysis of logging, that of sawmilling suggests that technological change may be lessening the demand for skills and that automation of many processes is reducing not only the physical but also the mental effort of workers. The automation of sawmill processes was foreseen by at least one expert two decades ago. In testimony before the U.S. Senate Select Committee on Small in Business in 1959, Fred C. Simmons described the sawmill of the future: "The sawmill proper will employ no more than five or six men. None of these will do hard physical work. This will be done by machinery. So will much of the mental work too. Many machines will be controlled by other machines" (U.S. Senate Select Committee on Small Business 1959).

It should be kept in mind that the foregoing discussion has been concerned with the skill of machine operators and helpers and not with engineers and mechanics. In most any situation involving heightened sophistication of machinery, there is a greater input on the part of the machine designer and the mechanic who keeps the machine running. Comments by operators of whole-tree yarding and chipping systems emphasize the importance of good mechanics on the job.[4] A recent Canadian study (Boyd 1977) showed that 1 of every 4 hours on logging jobs is lost because logging machines are out of service, and that up to three-quarters of the downtime can be eliminated through proper maintenance and repair procedures.

The implications of technological change on

training in the forest industry are unclear, to say the least. But the following tentative conclusions are offered.

- The process of mechanization in the industry should probably be viewed as one in which skill demands, rather than increasing across-the-board, become concentrated in a few key occupations, primarily those that have the responsibility for mechanical maintenance. Thus the MPIT of mechanics has become very high in relation to that of other workers.
- The evolution of mechanization in logging may still be at a stage where it enhances the MPIT of machine operators, but in the most highly mechanized operations this may not be true.
- Technological progress in sawmilling has probably reduced the skill requirements and the MPIT of machine operators.

Labor market characteristics

The need for training in forest industry depends to a great extent on whether there already are qualified workers in the labor force and the ability of the industry to attract and hold them. Since the labor situation in forest industry shows considerable change over time, among geographic areas, and among firms of different size or even different management philosophies, this subject can be discussed only in the broadest and most general of terms. Perhaps the best approach to the subject is through a brief historical sketch.

Forest industry has had an ample supply of labor over most of the post-World War II period. During the 1950's and 1960's, there was a large surplus of rural labor resulting from declining demand for farm workers. Employment in mining, another source of rural employment, was also dropping during this period. While many unemployed rural people migrated to urban areas in search of work, many others remained, caught in the backwash of postwar prosperity that was sweeping most of urban America (Marshall 1974; Sufrin and Buck 1963). Those who remained in rural areas contributed to a large labor pool for rural industries such as the forest industry (White 1965; Manthy and James 1964). Many of these people were readily employable because their farm background had given them familiarity with logging and milling equipment and practices (Wolf and Nolley 1977; Bond 1972a; White 1965).

Throughout this period, both segments of the industry were characterized by a large number of small firms, many of which were in and out of production as markets fluctuated. In both woods and mills, layoffs were common among the smaller firms when markets turned downward. In the woods, workers could rarely depend on more than 40 weeks of work because of adverse weather. The pay was low, the work physically demanding and hazardous, and working conditions were often poor (Wolf and Nolley 1977; Bond 1972b; Cottell 1972; White 1965; Hamilton et al. 1961).

Because of these conditions, workers attracted to the industry tended to be poorly educated and lacked motivation and reliability (Bond 1972c; Hamilton 1963). They tended to look upon the work as temporary and were quick to leave when another opportunity arose. Both quit rates and absenteeism were (and still are) among the highest in all of industry (Wolf 1977).

Much of what has been written about the labor problem of forest industry has described the problem as one in which the industry could not recruit sufficient numbers of workers with required skills, given the wages and working conditions that the industry felt it could offer (Granskog and Manthy 1970; Bromley 1957; Jenkins 1968). When fears of a wood shortage erupted, as they do periodically in times of high market demand (particularly in the pulpwood industry), the solution advocated by many was an active program of recruitment and training. In the case of pulpwood in the Southeast, closer analysis implicated the sharp increases in demand for wood and the inability of the wood delivery system to respond readily, rather than deficiencies in the labor supply (Hamilton et al. 1961; Pikl 1960).

Another and somewhat different way of viewing the labor problem in forest industry results if we ask the question: Is it really a deficiency of skills that has posed a problem for the industry, or does the deficiency lie in other attributes of the workers? In this re-

gard it is helpful to consider the theory of the dual labor market.

Whereas traditional labor market theory is based on the concept of a single market, the theory of the dual labor market holds that there are actually two markets—primary and secondary. The labor market conditions that have prevailed in much of the forest industry are similar to those described for the secondary market.

The primary market, according to Piore (1970), who formulated the theory, offers jobs that provide high wages, good working conditions, employment stability and job security, and chances for advancement. The secondary market offers jobs with low pay, poor working conditions, high variability in employment, and little opportunity to advance. But not only are there great differences between jobs in the two markets, the people who occupy them tend to exhibit different behavior. According to Piore, "the most important characteristic distinguishing primary from secondary jobs appears to be the behavioral requirements they impose upon the work force, particularly that of employment stability. Insofar as secondary workers are barred from primary employment by a real qualification, it is generally their inability to show up for work regularly and on time."

Piore suggests that entry into the primary labor market is not denied by lack of skill—recall we have already noted that most employers in industry are not greatly concerned with specific skills when hiring—but by the lack of a work ethic that gives the worker the attitude and motivation appropriate to the demands of the job.

If the theory of a dual labor market has any applicability to the labor problems for forest industry—I believe it does—then the industry's problem has not been a shortage of skilled labor as much as a failure to "buy" the desired worker behavior. The syndrome of quality jobs in terms of wages, working conditions, and other factors, matched by the quality of the workers attracted to those jobs, has existed. As one progressive logging manager put it, "There's no such thing as cheap labor."

If this analysis is accurate, then recruitment and training programs in the industry are doomed to failure unless the job qualities are upgraded. In the absence of such upgrading, the types of workers attracted to training programs are likely to be the same as those attracted to the jobs, and will exhibit the same degree of motivation, absenteeism, and quit rate.

To what the extent firms in the forest industry have problems of labor supply, it is difficult to see how those problems can be solved by training submarginal workers for submarginal jobs (Granskog and Manthy 1970). A more promising solution is creating jobs that will enable the industry to bid for workers in the primary labor market.

It is significant that the few successful training programs in the industry, such as that of Great Northern Paper Company, provide relatively high wages and are administered by those who can be selective in recruiting trainees. These factors, together with the quality of the resulting work force, suggest that Great Northern is tapping the primary labor market.

To some extent, better jobs are being created as a result of mechanization and changing industry structure. A key factor in promoting these changes is the turnaround in rural employment (Beale 1976; Marshall 1974). Farm employment has stabilized and employment in mining is increasing. A trend toward rural industrialization has created greater opportunities for manufacturing employment in small towns. All of this constitutes a move toward economic rebirth of rural areas that is predicted to continue in the foreseeable future, and will increasingly force the forest industry into greater competition for labor.

There are additional factors that will tend to intensify the competition for labor in the future, including a decline in both the rate of entry of young people into the labor force in the 1980's and the number of people available for jobs that the U.S. Department of Labor describes as "lower level" (Department of Labor 1976; Wool 1976).

Mechanization—through its effect on capital-labor ratios, labor productivity, wage rates, and job conditions—offers the industry an opportunity to compete for labor under a tighter labor supply. But there will remain

some strong disincentives to large infusions of capital and conversion to fully mechanized operations, especially in logging. The characteristics of the timber resource—its scatter, size, and accessibility—will continue to pose constraints on profitable capital input. Highly mechanized operations often require clearcutting of timber, and environmental constraints may limit its use. Increasing fuel costs and the cost of capital equipment itself will have to be reckoned with.

And then there are certain institutional factors that favor small, labor-intensive operations, such as workmen's compensation statutes that permit small employers to avoid paying insurance premiums. All of these factors tend to impede the process of mechanization, and together with higher labor costs, constitute a stern test of the industry's efficiency. The real skill problem in the future is likely to be in management rather than labor.

SUMMARY

Most of the training of workers in the forest industry is informal and takes place on the job. It is difficult, if not impossible, to assess the extent and quality of this training; but studies in other industries have shown that this method of training is favored by both management and labor. On-the-job training is easier to accomplish in sawmilling than in logging because of the concentration of workers and the "assembly line" nature of millwork. However, in both segments of the industry there is a reluctance to incur training costs because of the transferability of skills from firm to firm. A critical element in effective on-the-job training is the quality of management and supervision. The small operator in the forest industry is usually ill prepared to fulfill the managerial requirements of effective on-the-job training.

There has been little formal training in forest industry, and many efforts have proven unsuccessful—the chief reason apparently being the quality of trainees attracted to the programs. Notable exceptions include programs offered by two postsecondary vocational-technical schools and a large pulp and paper company in Maine. Formal training programs have shown greater success when trainees were selected carefully and were guaranteed a good wage during and after training.

Vocational training programs in wood harvesting at the high school level are of questionable value, and support of such programs by the forest industry may not be justifiable from the standpoint of social welfare or the long-term interests of the industry. In the long run, the industry can best be served by having access to a labor force that is educated to its highest potential, adaptable to changing technology and skill requirements, and motivated toward high performance and self-improvement.

Training for forest industry occupations in connection with public manpower programs has been a failure, both in the United States and Canada, largely because the goals of these programs have differed from the recruitment and training goals of the industry. There has been little opportunity to screen trainees, and the relatively low pay and poor working conditions in the industry have precluded the attraction of competent trainees.

Manufacturers of equipment for the forest industry provide little training for equipment operators but are beginning to offer an important service in the training of mechanical maintenance personnel. This is one of two areas in which the need for training is most acute and is likely to continue as machinery becomes more sophisticated.

Training programs offered by various Federal and state forestry agencies tend to concentrate on technical skills and ignore the needs for management training, which is the second area of acute need.

There is reason to question the commonly held assumption that increasing mechanization raises the level of required skills and leads to a need for more skill training. The assumption is probably more valid in logging than in sawmilling but even in logging the greatest need for intensified skill training as a result of mechanization is in the occupation of mechanic rather than machine operator.

What the forest industry has often viewed as a lack of skills might more accurately be described as a lack of motivation and unsatisfactory work behavior among workers attracted to the industry. The industry may be

operating in the "secondary" labor market, and thus recruiting and training submarginal workers for submarginal jobs.

The long-term oversupply of labor in rural areas has been the key factor contributing to low wage levels and poor working conditions in forest industry, but the rural labor supply is now changing and forest industry faces greater labor competition in the future. The industry may be able to compete in this labor market by mechanization and job upgrading, and there is evidence of a trend in this direction. However, there are a number of disincentives to mechanization with which the industry must contend, and there is no assurance that the pace of mechanization will be adequate to counter increasing labor costs.

In the future, most of the skills needed by the industry may be available in the more highly industrialized rural labor market and among the more highly educated workers in that market. Except for a few isolated areas where forest industry is the predominant economic activity, and where a few firms and public institutions may continue to offer formal skills training, on-the-job training should be adequate for the industry's needs for machine operators and helpers.

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Abstract

Between 1947 and 1955, 15 plots were established in the Eastern United States to evaluate chestnut hybrids under forest conditions. During the 1978 field season these test plots were reassessed and all living chestnut trees critically examined. Ten percent of the 250 surviving hybrid chestnuts were blight resistant, and had the timber form and rapid growth of the American chestnut, *Castanea dentata*.

INTRODUCTION

THE DESTRUCTIVE CHESTNUT BLIGHT fungus (*Endothia parasitica*) was first reported in this country in 1904. In less than 50 years, the deadly blight reduced our native American chestnut (*Castanea dentata*) from an important timber species to an understory shrub. However, the stumps of many trees still produce sprouts from the root collar, and this persistent sprouting has allowed the species to survive, though sprouts continue to be killed by the equally persistent blight. The history of the blight, its rapid spread, and early attempts to control it were described by Beattie and Diller (1954).

In 1925, the U.S. Department of Agriculture began an extensive chestnut breeding program aimed at developing blight-resistant hybrids that would grow rapidly, be able to compete with native tree species, and have the timber form of the American species. The hybrids were from crosses among American, Chinese (*C. mollissima*), and Japanese (*C. crenata*) chestnut species (Diller et al. 1964). Several years later, a similar chestnut breeding program was initiated at the Brooklyn Botanic Garden and later transferred to the Connecticut Agricultural Experiment Station.

The Department of Agriculture also imported a large quantity of Asiatic chestnut seed. One selection of seed from Nanking, China, (Plant Introduction #58602) proved superior in blight resistance, tree form, growth rate, and nut production (Diller et al. 1964).

By the late 1940's, several thousand hybrids from controlled crosses had been produced. Between 1947 and 1955, 15 test plots were established by Dr. Jesse D. Diller, formerly of the Department of Agriculture, in cooperation with others to evaluate under forest conditions the hybrid chestnuts from the USDA and the Connecticut Agricultural Experiment Station and the Chinese chestnut selection (PI-58602) (Diller et al. 1964).

METHODS

A total of 1,746 trees were planted in the 15 test plots. The USDA nursery at Glenn Dale, Maryland, contributed 500 hybrid chestnuts (MD) and 541 Chinese chestnut (PI-58602) seedlings, and the Connecticut Agricultural Experiment Station's Hamden nursery provided 705 hybrid chestnuts (CT). The Chinese chestnuts were interplanted on 14 of the 15 test plots so that the growth rate, tree form, and blight resistance of the hybrids and the Chinese introduction could be compared. The plots were established on cleared forest land of above-average hardwood site quality. All of the plots were planted in the spring except the Missouri plot, which was planted in early winter. The trees were planted randomly at a spacing of 10 x 10 feet.

The 15 plots were inspected in August and September 1963, and the height and diameter at breast height (dbh) of 20 to 25 of the most promising trees in each plot were measured. The results of this inspection have been reported (Diller et al. 1964).

Early in 1978, the author reexamined the 15 chestnut plots and assessed their current potential. Every living chestnut tree on the 15 plots was examined in the spring and early summer and data on growth, blight resistance, and tree form were recorded. The dbh was measured to the nearest tenth of an inch; height was measured with a Relaskop,[1] where

[1]The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

possible, or estimated, and recorded to the nearest foot. Mean diameter and height for each of the three groups were computed from a weighted value depending on the number of trees in each class.

RESULTS AND DISCUSSION

Generally, survival of the three groups of chestnut trees was poor (Table 1). In some instances, the chestnuts were not tended properly after they were planted. Without release cutting, many chestnut trees were unable to compete with native woody sprout reproduction, and eventually died. Survival of the Chinese chestnuts was 37 percent compared with a survival rate of 27 percent for the Connecticut hybrids and 12 percent for the Maryland hybrids.

Data on tree size were grouped into seven 2-inch diameter classes and seven 10-foot height classes. The percentage of trees in each diameter and height class, based on the total number of trees in each of the three groups, is shown in Tables 2 and 3. Mean diameter and height for each of the three groups are also shown in these tables.

Blight-susceptibility categories were determined by signs and symptoms of blight. Such evidence included the number and size of cankers present, presence of sprouts where

Table 1.—Survival of three groups of chestnut trees in 15 test plots, 1978

Plot no.	Location	Year established	Hybrid				Chinese chestnut		Total	
			CT		MD					
			Planted (no.)	Survival (%)	Planted (no.)	Survival (%)	Planted (no.)	Survival (%)	Planted (no.)	Survival (%)
1	CT	1947	50	34	23	17	58	34	131	31
2	TN	1947	51	12	22	32	55	53	128	33
3	OH	1948	25	12	37	11	17	35	79	16
4	SC	1948	66	11	19	37	34	47	119	25
5	IL	1949	25	12	49	8	25	28	99	14
6	PA	1949	25	28	49	10	25	48	99	24
7	MI	1951	50	34	39	0	13	15	102	19
8	CT	1951	42	64	0	—	48	40	90	51
9	CT	1951	49	29	0	—	49	47	98	38
10	AR	1952	58	24	30	17	20	20	108	21
11	WV	1953	50	30	49	14	50	38	149	28
12	AL	1954	50	50	50	18	50	42	150	37
13	NY	1954	50	4	49	8	51	8	150	7
14	MO	1954	64	11	34	6	46	37	144	18
15	NH	1955	50	48	50	8	0	—	100	28
All plots			705	27	500	12	541	37	1746	26

Table 2.—Surviving trees by diameter class

Group	No. of trees	Diameter class							Means
		2	4	6	8	10	12	14	
		Percent							*Inches*
Chinese 58602	199	15	20	31	23	9	1	1	6.1
CT hybrids	188	24	21	22	24	8	1	—	5.5
MD hybrids	62	13	19	34	14	13	5	2	6.3
All groups	449	18	20	28	22	9	2	1	5.8

Berry, Frederick, H.
1980. **Evaluation of chestnut test plantings in the Eastern United States.** Northeast. For. Exp. Stn., Broomall, Pa.
5 p. (U.S. Dep. Agric. For. Serv. Res. Pap. NE-454)

In the spring and summer of 1978, fifteen chestnut test plots that had been established between 1947 and 1955 were reexamined and all living chestnut trees critically evaluated. Ten percent of the 250 surviving hybrid chestnuts were blight resistant, and had the timber form and rapid growth of the American chestnut, *Castanea dentata.*

165.72: 232.13: 443.3

Keywords: Chestnut test plots; blight-resistance; hybrid chestnuts

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Keywords: Chestnut test plots; blight-resistance; hybrid chestnuts

Table 3.—Surviving trees by height class

Group	No. of trees	Height class							Means
		10-19	20-29	30-39	40-49	50-59	60-69	70-79	
		Percent							*Feet*
Chinese 58602	199	13	11	10	22	34	9	1	43.4
CT hybrids	188	15	24	12	16	28	4	1	38.1
MD hybrids	62	3	16	18	19	34	7	3	44.7
All groups	449	13	17	12	19	31	7	1	41.4

Table 4.—Surviving trees by blight-susceptibility category, in percent

Group	Blight susceptibility				
	No blight	Light	Moderate	Heavy	Severe
Chinese 58602	57	31	8	3	1
CT hybrids	50	26	13	8	3
MD hybrids	53	27	11	7	2
All groups	54	28	10	6	2

Table 5.—Surviving trees by tree-form category, in percent

Group	Tree form				
	Excellent	Good	Average	Poor	Valueless
Chinese 58602	6	23	27	25	19
CT hybrids	3	15	36	19	27
MD hybrids	11	24	26	28	11
All groups	6	20	31	22	21

the main stem had died, and dieback of tops. The categories, though not as precise as other numerical data, are believed to be reasonable ones. It was seldom difficult to grade a tree. A surprisingly large number of the trees (54 percent) were in the blight-free category. Table 4 shows the percentage of trees in each category for the three groups of chestnuts.

The trees were rated for tree form in five categories ranging from excellent to valueless. Trees with a single, straight stem and timber form rated high; crooked, limby, multi-stemmed trees rated low. The percentage of trees in each class is shown in Table 5.

In 1964, the most promising hybrid was an American x Chinese back-crossed with the American parent, located in the Illinois plot. This hybrid appeared to have all the fine qualities of the American species, plus the blight resistance of the Chinese species. Developed by Russell B. Clapper, it was known as the "Clapper" chestnut. The hybrid was still blight resistant after 18 years, and was 8.1 inches in dbh and 51 feet high (Clapper 1963; Little and Diller 1964). Around 1970, the "Clapper" chestnut began showing symptoms of blight infection; it was dead in 1978 when the plot was examined.

The 50 most promising trees in 1978 are shown in Table 6. At the time of examination

Table 6.—Comparison of the most promising individual trees

Plot no.	Location	Plot age (years)	MD hybrids				Chinese chestnut (PI58602)			CT hybrids			
			Tree	Parentage[a]	Dbh (inches)	Height (feet)	Tree	Dbh (inches)	Height (feet)	Tree	Parentage[a]	Dbh (inches)	Height (feet)
2	TN	31					144	6.1	60				
4	SC	30	F-31[b]	CxCJ	12.2	74	F-65	9.5	56				
			F-88	?[c]	6.3	56	D-80	9.2	49				
							D-67[b]	8.4	52				
6	PA	29	44[b]	CxCJ	8.1	55	24	6.0	50	56[b]	Cx(JxJA)	8.8	55
										51[b]	Cx(JxJA)	8.6	60
7	MI	27					24	10.9	55	63	?[c]	7.1	55
										47	CxJA	6.4	50
										56	CxJA	6.1	55
8	CT	27					6-4	6.8	45	8-1	CxA	7.7	40
										9-2	CxA	6.0	35
9	CT	27					3-5[b]	7.8	55	17-7	(JAxJ)xC	8.6	55
							6-6	6.0	55				
10	AR	26	90	CxC	7.6	43				42	CxJA	8.0	55
			41	CxC	6.5	57				15	CxJA	6.2	49
11	WV	25					9[b]	10.0	60				
							6	7.8	55				
							32	7.5	55				
							38	7.3	50				
							47[b]	6.7	60				
12	AL	24	31	CxC[b]	13.2	73	75	11.0	55	126	(CxJA)(CxJA)	9.9	63
			23	CxCA	10.5	59	12	10.3	61	144	(CxJA)(CxJA)	8.2	55
			94	CxC	10.2	67	45[b]	10.0	58	28	(CxJA)(CxJA)	7.5	51
			3	CAxCA	8.2	49	29	8.0	53	59	(CxJA)(CxJA)	6.0	55
			52	CxC[b]	8.0	56	16	7.6	51				
							38	6.4	60				
							44	6.3	53				
13	NY	24					B-94	7.1	40				
							B-133	5.6	40				
14	MO	24					149	7.4	55				
							177	6.9	50				
15	NH	23								71	CxJA	6.4	40

[a]A = American Chestnut, *C. dentata*; C = Chinese chestnut, *C. mollissima*; J = Japanese chestnut, *C. crenata;* E.g. CxCJ = Chinese x Chinese-Japanese.

[b]Considered a promising tree in 1963.

[c]? = Unknown, e.g., parentage lost.

Figure 1.—Tree F-31, center, a Maryland hybrid, was the best tree on the plot in South Carolina. It was free of blight, had good timber form, and was the tallest tree on the plot (74 feet).

these trees were free of blight and had good to excellent timber form. Growth rates were above average. Some are excellent specimens from a forester's viewpoint (Fig. 1). Of the 50 trees, which represent 3 percent of the original population, 10 are Maryland hybrids, 15 are Connecticut hybrids, and the remaining 25 are Chinese chestnut (PI-58602). The 25 hybrid trees represent 10 percent of the 250 surviving hybrids. These 50 trees, along with the more than 300 trees in the no blight and light disease categories, offer a good source for further genetic studies toward the development of blight-resistant chestnuts.

SUMMARY

When the plots were established it was not expected that the hybrid chestnut trees would develop into a blight-resistant forest stand. The lack of a reliable means to vegetatively propagate selected hybrids has severely restricted their distribution. If a good vegetative-propagation technique can be developed for chestnut, the very best trees on the plots should be propagated and used to establish clonal plantings or seed orchards on a limited scale. Extensive forest plantings of hybrid chestnuts with the purpose of replacing our blight-killed native American chestnuts is not feasible; however, a breeding program could provide stock for selected plantings.

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Jensen, Keith F.

1981. Air pollutants affect the relative growth rate of hardwood seedlings. Northeast. For. Exp. Stn., Broomall, Pa.
5 p. (USDA For. Serv. Res. Pap. NE-470)

One-year-old seedlings of yellow-poplar (*Liriodendron tulipifera* L.), eastern cottonwood (*Populus deltoides* Bartr.), and white ash (*Fraxinus americana* L.) were divided into four groups. One group served as the control, and the other groups were fumigated for 12 hours per day with either 0.1 ppm O_3, 0.2 ppm SO_2, or 0.1 ppm O_3 plus 0.2 ppm SO_2. Two or three seedlings of each species were harvested twice a week for 6 weeks, and leaf area and new growth weight were determined. Data on leaf area and new growth were transformed to natural logarithms and fitted with a linear regression model. Relative growth rate was positive in all species-treatment combinations, but varied with fumigation treatment. Net assimilation rate was suppressed in cottonwood seedlings in all fumigation treatments, and in yellow-poplar seedlings in the SO_2 and O_3 fumigations. Relative leaf area growth rate of the cottonwood and yellow-poplar seedlings was reduced by all three fumigation treatments. White ash growth was not analyzed because statistically significant differences were not found.

425.1, 161.4

Keywords: Ozone, sulfur dioxide, relative leaf area growth rate

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Foliage Weight Distribution in the Upper Crown of Balsam Fir

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Abstract

A model was developed to predict the weight of foliage at each age on a branch for a given whorl from undefoliated balsam fir (*Abies balsamea* (L.) Mill.). The normal weight of foliage by age classes can be compared to the weight of foliage remaining on a branch to estimate recent, annual defoliation by spruce budworm (*Choristoneura fumiferana* (Clem.)). One branch from each whorl was sampled in the top half of each of 22 balsam fir trees in New Hampshire and New Brunswick. The foliage was separated by age, ovendried, and weighed. A system of equations was developed to predict the total foliage weight of a branch from variables that would be minimally affected by defoliation. A ratio was developed to estimate the proportion of foliage by each age class on a branch using whorl number, needle age, and flowering effect. The estimates of total foliage weight on a branch and the proportion of each age of foliage were combined to estimate the weight of foliage for each age on a given branch.

INTRODUCTION

THE SPRUCE-FIR FORESTS of Maine and eastern Canada are periodically attacked by the spruce budworm (*Choristoneura fumiferana* (Clem.)). In the larval stages, this forest defoliator feeds primarily on the current year's shoots, buds, needles, and staminate cones of balsam fir (*Abies balsamea* (L.) Mill.) and to a lesser degree, the spruces (*Picea* spp.). When budworm populations are extremely high and the current year's foliage is depleted, the larvae will also feed on older foliage.

By removing the current year's foliage—a highly productive segment of a fir crown (Clark 1961)—the tree's photosynthetic base is reduced, resulting in a decline of tree productivity. While it is clear that increased levels of defoliation lead to decreased stem radial growth (Mott et al. 1957), it has proven difficult to relate defoliation and growth reduction in a quantitative manner. With continued epidemic budworm populations resulting in declining growth, present growth and yield data will overestimate forest productivity. If the forest manager is to make an informed decision on pest control and cutting regimes, he must be able to estimate declining spruce-fir volume growth due to budworm attack.

To relate defoliation to loss of bole volume growth, it is necessary to (a) establish the defoliation history of a small group of trees and (b) compare the growth of these trees to a standard for undefoliated trees. Conventional defoliation estimates are based on visual assessment, by broad categories, of stands of trees. Since small groups of trees are not identified in these surveys, a more specific measure of defoliation was needed for this study.

To estimate recent defoliation, we compared the distribution of foliage by age class in a defoliated crown with that in an undefoliated crown. A statistical model, based on tree characteristics that are minimally affected by budworm attack, was developed to predict the amount of foliage in each age class of an undefoliated tree and compare it with that of a defoliated tree. These year-by-year differences produce an annual defoliation index for the recent past.

This paper reports on the development of this model for estimating the age class distribution of foliage by weight on undefoliated trees and outlines the application of the model in an index of historic defoliation.

METHODS

Foliage samples were collected from 12 dominant-codominant trees during the last 2 weeks of June 1964, from Green River, New Brunswick, and from 10 dominant-codominants sampled during the third week in July 1977, from northern New Hampshire. Trees were selected from even-aged fir-spruce stands on well-drained upland sites that showed no indication of recent disturbance. The separation of samples by space (250 miles) and time (13 years) provided a data base that is not peculiar to one region or one short climatic period.

For each tree, total height, crown length, and the distance of each whorl from the top of the tree was measured to the nearest 3 cm; diameter at breast height (dbh) was recorded to the nearest 2.5 mm. A "normal" branch (one without deformities, insect attack, unusual branching, or under excessive competitive stress) was selected from each live whorl in the top half of the crown. This section of the crown contains the greatest proportion of

new foliage and does not have the diversity of branching caused by stress from competing crowns. Sample branches were removed and the diameter measured at 2.5 cm from the bole of the tree. Each year's foliage was clipped, separated for each branch, ovendried, and weighed. The current year's foliage was not measured since needle growth was incomplete.

The combined data base, consisting of 251 branches from the top half of 22 balsam fir crowns, was:

Parameter	*Mean*	*Range*
Dbh (cm)	16.2	9.1 to 28.4
Height (m)	13.58	10.25 to 17.80
Crown length (m)	7.36	3.76 to 12.04
Whorls in full crown	24	16 to 35
Release age	46	36 to 60
Branch diameter (mm)	12	4 to 37
Branch foliage weight (g)	57.7	0.4 to 370.3
Density (stems/ha)	5,437	1,730 to 12,255

ANALYSIS

In order to predict the foliage weight on a branch by age, a three-step procedure was used. First, the total weight of branch foliage was estimated; second, the proportions of each age of foliage on a branch were determined; and third, the estimates of total weight and the ratios were combined to estimate the weight of each age of foliage on a branch for a given whorl.

A branch total foliage weight model

Combinations of independent variables, describing branch size and tree characteristics, were evaluated in a screening procedure to predict the total weight of foliage on a branch (Furnival and Wilson 1974). The independent variables used to describe branch size were: branch diameter, branch basal area, whorl age, and the distance of the branch from the top of the tree. Each variable has a positive, allometric relationship with foliage weight (Whitaker 1962; Loomis et al. 1966). Tree variables such as total height, dbh, crown length and width, release age, and number of whorls in the crown were also screened. Relevant branch and tree interaction variables such as branch diameter x whorl age, distance of the branch from the top ÷ crown length, total height ÷ release age were tried in the initial models.

With data from the 251 sample branches from New Hampshire and New Brunswick, the model showed no significant differences for the data between the two locations. The foliage weight model is:

$$\log W_{ij} = 0.128 + 1.467 \log (D_{ij} N_{ij}) - 0.963 \log N_j \quad (1)$$

where

W_{ij} = total weight of foliage on a branch from the i^{th} whorl on the j^{th} tree (g)

D_{ij} = diameter of the branch from the i^{th} whorl and j^{th} tree (mm)

N_{ij} = age of the i^{th} whorl on the j^{th} tree

and

N_j = total number of whorls on j^{th} tree.

Although the model, based on the pooled data, was highly significant with an R^2 of 0.95 and a $s(\overline{\log W})$ equals 0.023, equation (1) should not be used to predict the normal foliage weight on a tree defoliated by budworm. Continued defoliation could decrease the diameter growth of a branch, thus a model was needed to predict normal branch diameter if no defoliation had occurred. The branch diameter model is:

$$D_{ij} = 8.896 + 3.148 L_{ij} + 0.229 DBH_j - 0.144 A_j \quad (2)$$

where

L_{ij} = the length of the bole between the top of the tree and the i^{th} whorl on the j^{th} tree (m)

DBH_j = diameter at breast height of j^{th} tree (cm)

and

A_j = release age of the j^{th} tree.

The model was significant with an R^2 of 0.86 and a $s_{y \cdot x}/\sqrt{n}$ equals 0.117.

A similar problem occurs in the branch diameter model since the distance of the whorl from the top (L_{ij}) can also be affected by budworm defoliation. The budworm often feeds on the terminal bud, eliminating or stunting the normal tree height growth, thus affecting the spatial arrangement of whorls in the crown. The data suggested that, on an undefoliated tree, the whorls are about equally spaced through the length of the crown and can be described in the form

$$L_{ij} = \beta\ (L_j/N_j)\ N_{ij} \qquad (3)$$

where L_j is the total length of the crown of the j^{th} tree (m).

The coefficient β was estimated for each tree. The mean of the β's (0.99) for the 22 trees was not significantly different from 1.0, therefore the coefficient was set equal to 1.0 in the model. The regular spacing of whorls in the crown indicates that terminal growth in defoliated trees, over the short term, can be estimated by predefoliation height growth.

The three models constitute a system of equations and the coefficients were estimated by two-stage least squares (Goldberger 1964). Distance of the i^{th} branch from the top of the tree was predicted from equation (3). The predicted distances (L^*_{ij}) were substituted for L_{ij} actual distances in the branch diameter model and the coefficients were recalculated. The last step was to substitute the predicted branch diameter (D^*_{ij}) for the actual branch diameter in the branch weight model.

Our simultaneous branch weight, branch diameter, and branch distance model is:

$$\log W_{ij} = -0.094 + 1.486 \log (D^*_{ij}\ N_{ij}) \quad (4)$$
$$- 0.836 \log N_j$$

$$D_{ij} = 8.290 + 2.751\ L^*_{ij}$$
$$- 0.104\ A_j + 0.168\ DBH_j$$

$$L_{ij} = (L_j/N_j)\ N_{ij}.$$

The relationship of the branch foliage weight to tree variables that are minimally affected by defoliation was significant with an R^2 of 0.91, a $s(\overline{\log W})$ equals 0.031 and is shown in Figure 1 for various size crowns of a hypothetical tree.

Defoliation would also decrease bole diameter growth thus influencing the dbh of trees under budworm attack. Therefore "normal" dbh of a tree that has been defoliated must be estimated. Radial increments at dbh were available for the 10 New Hampshire sample trees. These data were used to evaluate the relationship between the last 5-year radial growth and the previous 5-year radial growth. The model used was

$$I_{1j} = \beta\ I_{2j}$$

where

I_{1j} = last 5-year radial increment at breast height on tree j

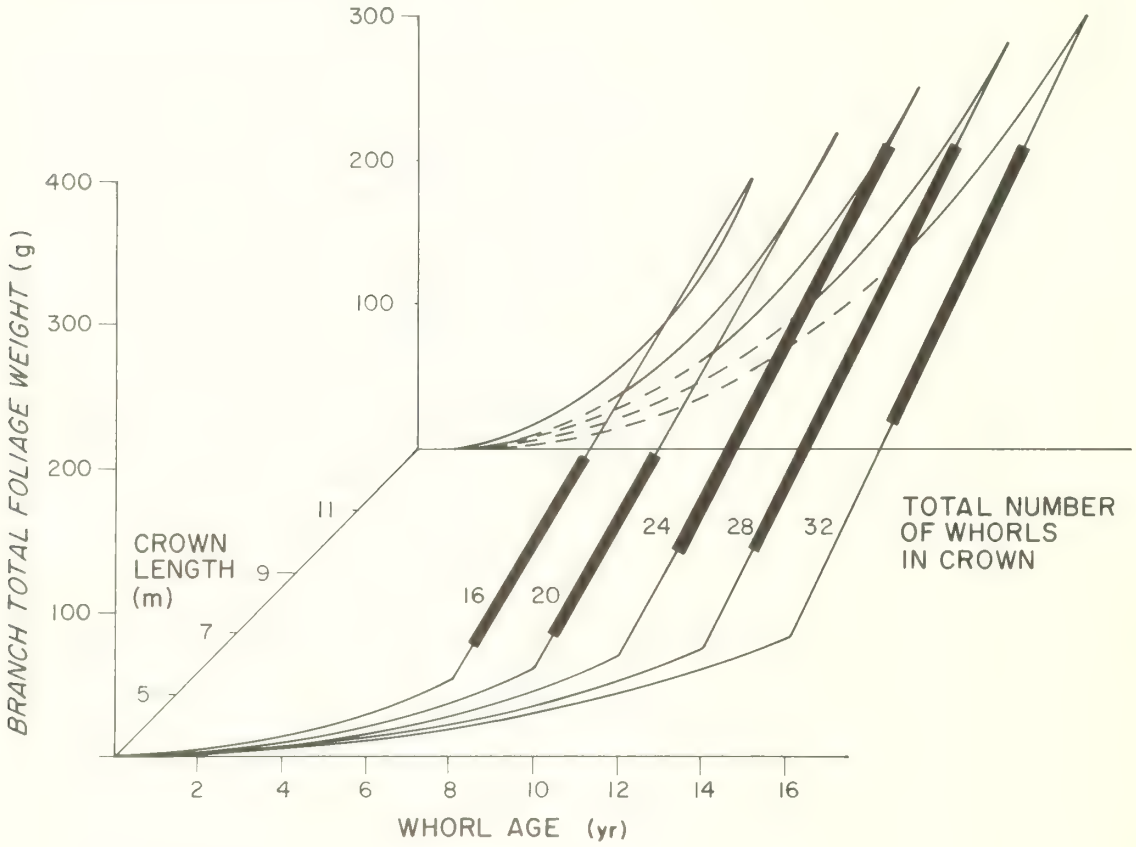
I_{2j} = previous 5-year radial increment at breast height on tree j.

The mean of the β coefficient (0.96) was not significantly different from 1.0. Therefore, the normal growth and hence normal dbh can be estimated from the radial growth increment prior to defoliation and the previous dbh.

Foliage age-class ratio

In order to create an index for estimating a 5-year annual defoliation history, the

Figure 1.—The weight of foliage on a branch by whorl age for the top half of various size crowns on a 45-year-old, 14-cm dbh balsam fir. The heavy lines indicate the range of crown lengths sampled.



branch foliage weight must be separated into age classes. To predict the distribution of foliage by age, the weight of an age class of foliage was recoded as the ratio to the weight of foliage the same age and older. In this manner the foliage in each age class was predicted and then was not considered in the estimation of the older age classes. By definition, this foliage age-class ratio is equal to 1.0 when whorl age is equal to foliage age.

When the foliage ratio for each age class was plotted against the branch variables, a negative exponential relationship was evident. Whorl age proved to be the best branch variable predictor of the foliage age-class ratio for each age of foliage from the New Hampshire and New Brunswick trees (Fig. 2).

Differences in the relative position of the foliage ratio curves were evident between the two areas over the age classes and were found to be attributable to the periodic flowering of balsam fir. Every 2 or possibly 3 years, balsam fir produces a generous supply of cones which results in a decrease of foliage production (Morris 1951). Flowering records and the presence of cone scales indicated that the New Brunswick trees flowered concurrent with 2- and 4-year-old foliage production, while the New Hampshire trees flowered with 1-, 3-, and 5-year-old foliage production. The alternating pattern of age-class curves for New Brunswick and New Hampshire repeats this pattern of flowering (Fig. 2).

The foliage ratio data from both locations were combined and a single equation model, using whorl age, needle age, and a dummy variable to describe the effect of flowering, was developed. Flowering effect was added in

Kleinschmidt, Steven, Gordon L. Baskerville, and Dale S. Solomon. 1980. **Foliage weight distribution in the upper crown of balsam fir.** Northeast. For. Exp. Stn., Broomall, Pa.
8 p, illus. (USDA For. Serv. Res. Pap. NE-455)

A model was developed to predict the weight of foliage at each age on a branch for a given whorl from undefoliated balsam fir. The normal weight of foliage by age classes can be compared to the weight of foliage remaining on a branch to estimate recent, annual defoliation by spruce budworm.

518.9:532:174.7

Keywords: *Abies balsamea* (L.) Mill., biomass, defoliation

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whorl branches from the top half of balsam fir crowns and (b) the proportion of each age class of foliage on these branches. By combining these two estimates, the normal weight of foliage by age class on a branch can be compared to the weight of foliage remaining after budworm attack to estimate annual, historic defoliation for an individual tree. To use the normal foliage models as a standard in a defoliation index, it was necessary to relate branch foliage weight to tree variables that are minimally affected by the loss of foliage. However, when a portion of a tree's photosynthetic base is destroyed, the entire tree can be affected. Thus, to predict the normal total foliage weight on a branch for trees under budworm attack, models were developed to estimate branch diameter, bole height, and radial growth from predefoliation performance (equation 4). On the other hand, the proportion of each age class of foliage on a branch was readily estimated in a single equation by variables that are little affected by defoliation (equation 5).

The models developed between total branch foliage weight and tree variables indicate that dbh and release age are linearly related to branch diameter but exponentially related to branch foliage weight. This agrees with the exponential relationship between dbh and tree foliage weight noted by Kittredge (1944). Similarly, there is a negative, exponential relationship between release age and total foliage weight which has also been observed by Baskerville (unpublished data) in fir trees ranging in age from 30 to 85 years.

The models can be used as a standard for estimating historic defoliation and should be applied primarily to trees from good, upland sites. Nodal branches should be sampled through the upper crown of a defoliated tree, the foliage separated by age, ovendried, and weighed. Normal weights for each age of foliage are then predicted by equation (6) for each branch sampled. Predicted and actual foliage weights are summed for each age of foliage over all branches sampled on a tree and then compared. The difference between predicted and measured foliage for each of the five age classes is defined as the weight of needles destroyed by the budworm in the year when that age class was current foliage. The weight of foliage destroyed divided by the predicted foliage weight in each age class is the annual index of defoliation over each of the past 5 years.

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Costs and Environmental Impacts of Harvesting Timber in Appalachia with a Truck-Mounted Crane

by J. N. Kochenderfer
and G. W. Wendel

CLEMSON UNIVERSITY
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Abstract

A truck-mounted crane was used to yard and load timber from a 30-acre sale in a 140-acre watershed in the mountains of north-central West Virginia. A total logging cost, excluding road costs, of $44.35/M bm for logs delivered to a mill 20 miles away was comparable to that reported for wheeled skidders. Road costs with gravel would add $55/M bm, without gravel $26/M bm. Roads built to these standards held sediment production within the range (0.05 to 0.10 ton/acre/year) expected for undisturbed forested watersheds. Residual stand damage caused by this system was also comparable to other systems and was concentrated on small trees.

INTRODUCTION

IN THE APPALACHIAN MOUNTAINS most timber is harvested by some form of ground skidding. Wheeled skidders appeared in the late 1950's, and are now the most widely used. In our opinion, the major problem with wheeled skidders is their requirement for a dense network of roads. Bulldozed skidder roads, often improperly planned and poorly constructed, also may be esthetically unacceptable. The customary practice is to space roads 100 to 150 feet apart, thus reducing the distance the winch line must be pulled to trees. Skidders usually log about 20 acres per mile of road, exposing about 10 percent of the soil surface in roads and log landings (Kochenderfer 1977).

The public is concerned about the environmental impacts of timber harvesting, especially muddy streams and hillsides crisscrossed with numerous bulldozed roads. The reduction of these impacts often increases logging costs in proportion to the volume and value of the timber harvested. In the West, where the volumes per acre harvested are high and the land ownerships generally large, highly sophisticated cable systems are used. These require fewer roads and are environmentally more acceptable than ground skidding systems. In the East, with relatively small ownerships and generally low value-volume stands as compared to the West, little is known about the economics of cable logging (Kochenderfer and Wendel 1978).

This article describes a simple cable system used for several years by a logger in the north-central part of West Virginia. It is a truck-mounted crane used for both yarding and loading. The crane is self-propelled, a desirable feature where ownerships are small and scattered. Kochenderfer (1977) reported that this machine operated from roads spaced at about 250-foot intervals, logged about 31 acres per mile of road, and exposed about 8 percent of the soil surface in bulldozed roads and landings.

The cost of the second-hand, truck-mounted crane, plus the necessary modifications, was less than $10,000. The original crane was removed from its 20-ton carrier and replaced with a smaller 6-ton crane with a 25-foot boom (Fig. 1). This modification provided a stable base for yarding and reduced the overall machine weight, yet permitted the machine to operate on narrow roads (12 to 15 feet wide). The machine has two drums, but only the one carrying 400 feet of 3/8-inch cable is normally used. Most of the logs are yarded tree length and then bucked in the road. In yarding, the cable is pulled out to the logs, tongs are set, and the log is pulled to the road. The swing boom helps to guide logs around obstacles while they are being winched and

Figure 1.—Truck-mounted crane.

then decks them on or along the roads, eliminating the need for large landings. The lift provided by the boom raises the front of the log off the ground, which results in less ground disturbance and damage to road berms. Also, logs are usually cleaner than those pulled by ground skidders.

A typical access system for this machine consists of a climbing road with contour roads branching off at 250- to 300-foot intervals. Generally, the truck-mounted crane operates best on roads with a grade of less than 10 percent.

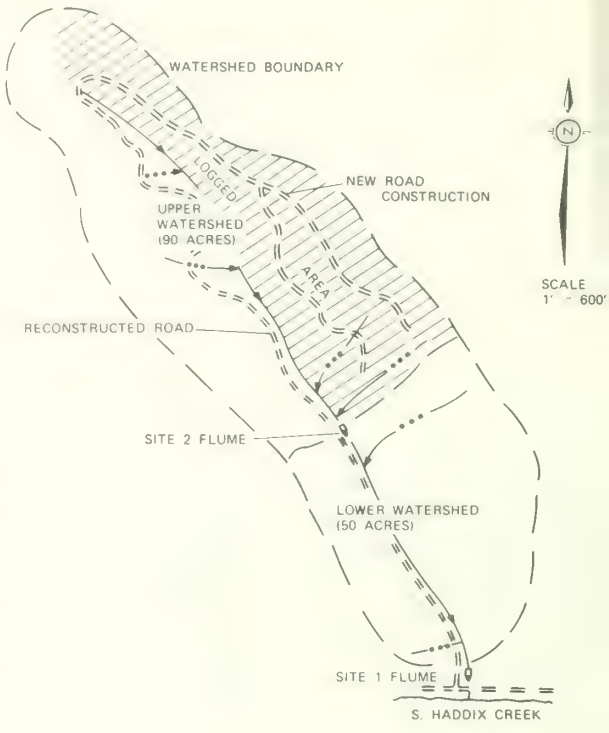
STUDY AND METHODS

In the spring of 1977, we set up a 30-acre timber sale in a 140-acre watershed on the Monongahela National Forest near Parsons, West Virginia, to be logged with a truck-mounted crane. Our objectives were to determine logging and road building costs, and to measure the impacts of truck-mounted crane logging on the residual stand and stream quality.

Logging costs were determined from a daily tally of man and machine hours, from the start of road building until the last log was delivered to the mill. The costs do not include allowances for profit and risk or cost of stumpage. The assumption is that the stumpage was purchased by someone else and that the logger contracted to cut and move the timber to the mill, the common practice in this section of Appalachia. Road costs included bulldozing, construction of drainage dips, culvert installation, and graveling. During logging, we tallied man and machine hours separately for yarding, trucking, and felling.

Streamflow was measured at two sites using H-type flumes equipped with FW-1 water-level recorders: site 1 at the mouth of the watershed, and site 2 at the stream just below the boundary of the cutting areas (Fig. 2). Some pertinent watershed dimensions are listed in Table 1. Five-tenths of 1 percent of the flow through each flume was sampled by a Coshocton wheel and 10 percent of this was stored in a 600-gallon tank (Fig. 3). A sample of the tank contents was taken weekly, more often during high flows. Sediment was determined by a standard filtering method (AAPSE 1972). Streamflow was determined from recorder charts and rating tables for H-type flumes (Holtan et al. 1962). Coarse sediment (bedload) collected in the flume approach box at site 1 was periodically weighed and added to the total. This material consisted mainly of sand and larger size particles. Finer sediments in the collection tank were mostly silt and clay. Some storm flows were sampled at 15-minute intervals, using ISCO automatic samplers equipped with a floating intake at site 1.

Figure 2.—Map of the study area on the Monongahela National Forest.



At 40 randomly selected points, a 10-factor prism was used to tally all residual trees larger than 1.0 inch in diameter at breast height (dbh), and these were examined for damage. Damage to residual trees was classed as abrasion, skinned, root damage, or destroyed.

For the logging operation, 4,300 feet of existing road were reconstructed and upgraded to provide access to the sale area (Table 2) which lay 460 feet above the watershed outlet. An additional 4,300 feet

Table 1.—Watershed dimensions

Watershed	Area			
	Watershed	Stream channel	Roads	Sediment source area[a]
	Acres			
Upper	90	.53	3.56	4.09
Lower	50	.28	.82	1.10
Total	140	.81	4.38	5.19

[a]Area is the acreage of stream channel and roads.

Figure 3.—The 3-foot H-type flume and 2-foot Coshocton wheel at site 1.

of new road was constructed within the sale area (Fig. 2). About 67 percent of the climbing (existing) road had a grade of 10 percent or less, while 81 percent of the new road had grades of less than 10 percent.

Metal culverts were placed at crossings of all live streams and seeps. All other drainage was taken care of by broad-based dips, spaced at 200-foot intervals, patterned after those of Hewlett and Douglass (1968) and Cook and Hewlett (1979).

RESULTS

Road cost

The cost for the reconstructed road was $5,855 per mile, including 600 tons of 3-inch clean stone surfacing at $5.74 per ton. The D-6 tractor time was 20.5 hours (25 hours per mile), with 6 of these hours used to construct 19 broad-based drainage dips. Spreading gravel and final dip shaping required 23 hours (28 hours per mile) of JD 450 tractor time. Installation of two culverts required 5 hours of labor. Road reconstruction without stone would have cost $1,061 per mile.

The newly constructed road cost $3,673 per mile, including 200 tons of gravel. Only the softer fills and a few of the dips were graveled. Approximately 46.5 hours of D-6 tractor time (57 hours per mile) were required to bulldoze the road and construct 22 dips. Spreading gravel and final dip shaping required an additional 7.5 hours of JD 450 tractor time. Constructed without stone, this road would have cost $2,078 per mile. Each drainage dip took about 20 minutes to construct and required about 20 tons of gravel.

Table 2.—Average dimensions of the road system

Road	Cut bank height	Bottom of cut bank to:		Drainage dip intervals[a]	Side slope	Road grade
		Edge of berm	Toe of fill			
	Feet				*Percent*	
Newly constructed	3.9	15.2	20.2	225	39	7
Reconstructed	5.7	17.0	23.7	200	48	9

[a]Distance between low points of two adjacent dips.

The total cost of a graveled dip averaged $128.

To reduce road building costs, cut banks were not sloped. Clearing and grubbing were done in conjunction with road building, and slash was simply pushed away from the road.

Logging study

It took 724 man hours (90.5 man days) to cut, log, and transport the 140 M bm (International 1/4-inch Kerf rule) to the mill. The five-man crew averaged 7.7 M bm per day or 38.5 M bm per week at the mill, located about 20 miles from the logging area. Total labor cost at $6 per man hour was $31.02 per M bm (Table 3).

Generally, the trees were yarded as they fell. Thus the feller was not continuously cutting trees, but assisted in bucking, yarding, and loading. Trees most distant from roads were felled first to avoid yarding them through slash. To determine machine costs, we divided total hours of operating time by volume logged for each piece of equipment and then multiplied that product by the hourly machine rate. Total machine cost, not including road construction, was $44.26 per M bm. Costs for the graveled road system added about $55 per M bm, about $26 if no gravel was used. Thus, the total logging cost from the stump to the mill was $99.26 per M bm on graveled roads. If no gravel had been used, the usual case in Appalachia, total costs would have been $70.26 per M bm — plus any additional cost resulting from operation on ungraveled roads.

Sediment production

Sediment production was monitored continuously for 2 years. Since these data include the period during road building and logging, they probably include the period of maximum sediment production.

As expected, most of the sediment was produced during occasional large storms. One major storm spanned a 2-day period, producing 47 percent of 1977-1978 sediment discharge. Two other major storms spanned a 6-day period, accounting for 50 percent of the 1978-1979 sediment discharge. Most of the sediment during both years was exported when peak flows approached or exceeded 2.6 ft^3/s. In both

Table 3.—Summary of logging costs and time, using a truck-mounted crane

Item	Hours/M bm	Cost	
		Per hour	Per M bm
		Dollars	
Labor			
Felling & bucking	1.87	6.00	11.22
Yarding	1.34	6.00	8.04
Loading	0.91	6.00	5.46
Hauling	0.94	6.00	5.64
Maint. & Repair	0.08	6.00	0.48
Final road work	0.03	6.00	0.18
Total			31.02
Machine time			
Felling & bucking	1.87	0.69	1.29
Yarding & loading	0.97	3.36	3.26
Hauling (incl. loading time)	1.26	5.98	7.53
Case 310 (final road shaping)	0.03	20.00	0.60
Crew pick-up	0.20	2.82	0.56
Total			13.24
Total logging cost			44.26
Road cost			
With stone	—	—	55.00
Without stone	—	—	26.00

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1980. **Costs and environmental impacts of harvesting timber in Appalachia with a truck-mounted crane.** Northeast. For. Exp. Stn., Broomall, Pa.
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375.1, 461, 116.28, 661

Keywords: Cable systems; partial cutting; forest roads; logging costs; sedimentation; stand damage

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.1, 461, 116.28, 661

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years of record, 90 percent of the sediment from the 140-acre watershed was exported in only 5 percent of the time.

There is no way to pinpoint the sources of this sediment. But since overland flow does not occur on most well-vegetated forest land (Hewlett and Hibbert 1967), the roads and stream channels are the only sediment sources possible. The area above site 2, which includes the logged area, produced the least sediment while the 50-acre area between sites 1 and 2 produced the most. When loss is expressed as tons/acre of source area, sediment export was at least twice as great from the lower part of the watershed. Part of this increase is attributed to disturbance during construction of the flume at site 2. Sediment production also was greater on the lower watershed since it contained 1,600 feet of reconstructed road, located at some places on a 60-percent side slope and within 50 feet of the stream. Some of the overcast material from this road slid to within a few feet of the stream during reconstruction. Although the road is close to the stream, gravel and closely-spaced, broad-based dips have protected the road surface from erosion and dispersed runoff. There was no observable movement of soil to the stream, even where recommended filter strip widths did not exist.

Sediment yield for the 2-year period is summarized in Table 4. This yield compares favorably with the 0.007 ton/acre-inch/year suggested as a base rate for undisturbed, well-stocked pine types in the Coastal Plain (Ursic 1977). Douglass (1975) concluded that normal erosion from fully stocked forests is generally less than 300 pounds/acre/year and results mainly from normal geologic erosion on stream channels and banks. The highest yearly rate we measured was from the lower watershed, 0.005 ton/acre-inch (46 ppm) or 208 pounds/acre. Expressed as tons/acre/year, these yields are similar to those summarized for undisturbed forest plots and small watersheds in the Eastern United States (Patric 1976). These rates are much less than the 1 to 5 tons/acre/year under which economic agriculture can be sustained on farmland (Klingebiel 1962).

Coarse sediment accounted for 24 percent of total sediment exported at site 1, only a negligible amount of coarse material was exported at site 2. The gravelly nature of the stream channel between sites 1 and 2 and the larger volume of flow in it probably account for this difference in coarse sediment export. Stream gradient above the two sites is not much different, averaging 10 percent above site 1 and 9 percent above site 2.

Organic matter comprised 25 percent (by loss on ignition) of the fine sediment measured in the collection tanks. Only 3.4 percent of the coarse sediment measured in the approach box at site 1 was organic matter. Twenty-one percent of total sediment production at site 1 was composed of organic matter.

The enormous variation of sediment production over time is illustrated in Figure 4. The hydrograph was generated when about 1.5 inches of rain fell during 2 days on 18 inches of melting snow. Sediment export peaked slightly ahead of streamflow. Fine sediment export was 2,304 pounds

Table 4.—Annual sediment production for 1977 and 1978

Watershed	Total per period		Per acre-inch of streamflow		Annual yield per acre of watershed		Annual yield per acre of sediment source area[a]	
	Tons							
	1977	*1978*	*1977*	*1978*	*1977*	*1978*	*1977*	*1978*
Upper	4.274	4.334	.002	.002	.048	.048	1.045	1.060
Lower	5.173	4.511	.005	.004	.104	.090	4.703	4.101
Total	9.447	8.845	.003	.003	.068	.063	1.820	1.704

[a]Area is the acreage of stream channel and roads.

Figure 4.—Relationship between sediment and streamflow with time for a 2-day period in February at site 1.

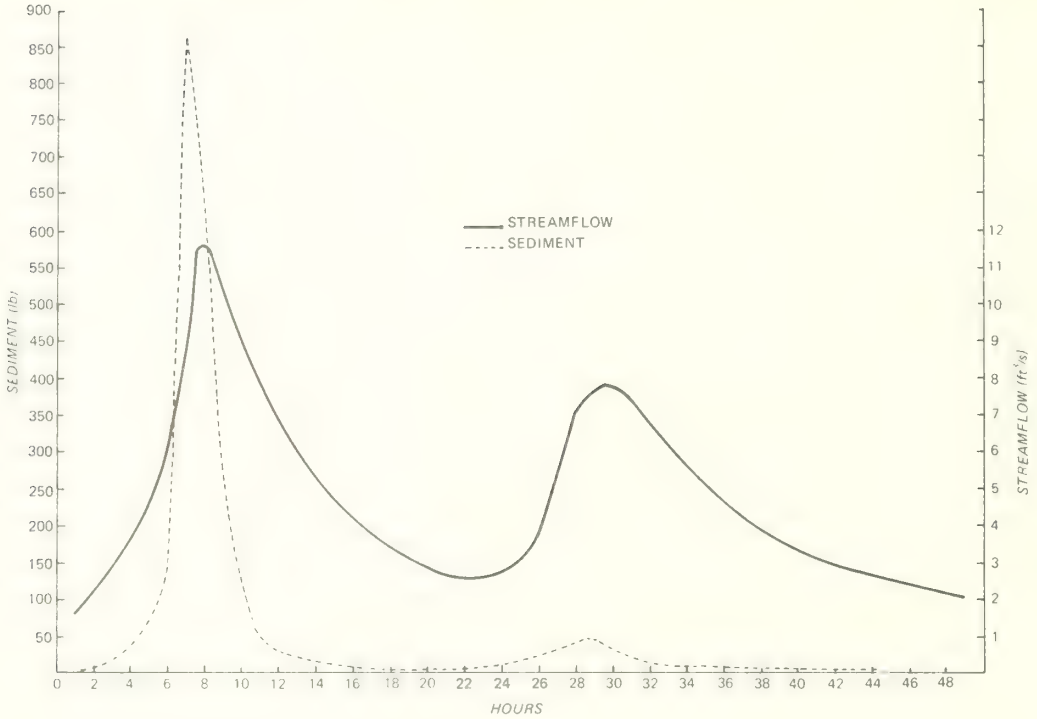
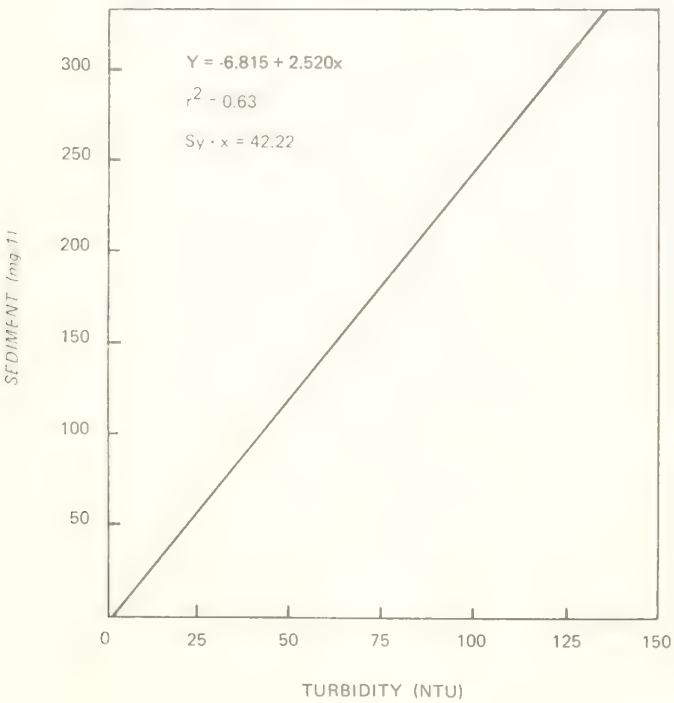


Figure 5.—The relationship between sediment concentrations and turbidity.



during the first 22 hours. The next 22 hours, when the second peak occurred on the hydrograph, only 263 pounds of fine sediment were exported. This illustrates a "flushing out" phenomenon commonly observed on all of our experimental watersheds. In addition to storm size and intensity, the interval between storms is an important variable influencing sediment loads on a given watershed. There were also 1,244 pounds of coarse material deposited in the approach box at site 1 during this 44-hour period. Most of this material was probably deposited during the first peak on the hydrograph. During periods when ISCO samplers equipped with a floating intake were used in conjunction with the Coshocton wheels, there was a close agreement in fine sediment export between the two sampling methods.

Turbidity of a water sample is the optical property that causes light to be scattered and absorbed by suspended and colloidal matter rather than being transmitted through the sample. Figure 5 shows the relationship between sediment concentrations and tur-

bidity. It is based on about 1,000 samples having turbidities up to 130 NTU. The validity of turbidity measurements as estimators of sediment concentration has been questioned by some authorities. The American Public Health Association (1975), for example, states that "Attempts to correlate turbidity with weight concentrations of suspended matter are impractical." Kunkle and Comer (1971), nevertheless, found a reasonably consistent relationship in Vermont, and Costa (1977) found a good correlation between turbidity and sediment concentrations in Maryland. Both authors pointed out that the relationships should be verified for the streams in question. The correlation on this graph is less than ideal but it does provide rough estimates of sediment concentrations on this watershed and perhaps for other watersheds having similar soil. Its reliability must be verified before use at other locations. Since turbidity measurements can be readily made in the field, this relationship affords a quick way to estimate sediment concentration, for example, in evaluating erosion control measures on logged areas.

Residual stand damage

There were 513 residual trees per acre larger than 1 inch dbh. Of these, less than 1 percent had abrasion wounds or root damage, 9 percent were skinned, and 1 percent were destroyed (Table 5). Sixty-three percent of the damaged trees were less than 6 inches dbh. Of the wounds on skinned trees, 52 percent were less than 6 in^2, 25 percent were between 7 and 25 in^2, and 23 percent exposed more than 25 in^2 of sapwood.

DISCUSSION

If we project the results obtained in this study, road construction costs on similar soils and topography will vary from about $2,000 per mile with no gravel and few culverts to about $10,000 per mile with complete graveling and more frequent use of culverts. In order to stay within these limits, the following rules of logging road construction should be observed:

- Use an operator experienced in forest road construction; use nothing smaller than a D-6 bulldozer or its equivalent.
- Use the bulldozer for right-of-way clearing.
- Make no effort to slope cut banks, sloughing off will occur naturally and road banks will eventually stabilize.
- Metal culverts and necessary ditching should be used on live streams and seeps; drainage from the road surface itself should be contained in broad-based drainage dips.
- Dips should be: constructed where road grades are 10 percent or less; flagged out after roads are roughed out; at least 100 feet long, i.e., from the start of the cut to the end of the fill; graveled with about 20 tons of clean, 3-inch stone except on rocky or shaley soil; and outsloped 3 to 4 percent at the low point to allow for drainage.
- If possible, allow newly constructed roads to settle several months before using.

Table 5.—Number of residual trees per acre damaged by yarding with a truck-mounted crane

Damage class	Dbh class (inches)			Total number per acre	Percent
	1 – 5	6 – 11	11 +		
Abrasion	0	< 1	0	< 1	< 1
Skinned	27	15	2	44	9
Root damage	0	0	< 1	< 1	< 1
Destroyed	5	0	0	5	1
Total	32	16	3	51	10

For this type of road, a bulldozer will often have to be used in conjunction with large trucks to spread gravel. Road rutting can be kept at a minimum by frequently changing wheel tracks when hauling.

In our opinion, the most important feature of this type of road is its residual value—it can be used for fuelwood harvesting, fire control, and a variety of other management activities. Roads built for rubber-tired skidders are often steep, poorly located, inadequately drained, and usually cannot be negotiated with other vehicles. Another value, frequently overlooked, is the good appearance of a properly constructed and drained forest road. Much of the criticism directed at timber harvest methods stems from objection to overly numerous, muddy, and generally unsightly logging roads.

The truck-mounted crane required fewer roads than the rubber-tired skidder; its mobility and swinging boom resulted in less damage to the residual stand, and provided a means for decking logs along the road. The boom lifted logs above the road berm, eliminating damage to the downhill side of the road. The logs were not skidded, so they were cleaner—important in bucking, and for mills with no debarker or other log-cleaning equipment. The investment probably was lower for a machine that both yards and loads than for a system requiring a skidder and a loader.

More extensive observation will have to be made to properly evaluate stand damage but we expect it to be at least as low as that observed on ground skidding systems.

Although topography dictated that the reconstructed road be located rather poorly in relation to the stream, sediment production was kept within limits expected for undisturbed forested watersheds. Erosion control on road sections adjacent to the stream was accomplished with additional gravel and close spacing of drainage dips. Allocating a larger percentage of available road funds to portions of the access that will receive the heaviest use—and to critical segments adjacent to streams—simply makes good sense. The rest of the access system was properly located relative to the stream and therefore could be built on a lower standard by using ungraveled dips and only spot graveling. This logging system lends itself well to winching trees away from the channel area and thus eliminates any need to operate equipment in this critical area.

Hewlett (1979), after monitoring a forestry operation in the far more erodible soils of Georgia, concluded that most of the sediment export due to the forestry operation was directly attributable to bad roading and channel-area damage by equipment. Our findings support his conclusion because we took the necessary precautions in these potentially critical areas and sediment production did not exceed that normally expected from undisturbed forest land.

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DUTCH ELM DISEASE CONTROL:

Performance and Costs

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William N. Cannon, Jr.
David P. Worley

USDA FOREST SERVICE RESEARCH PAPER NE—457 1980

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This is an updated revision of USDA Forest Service Research Paper NE-345, published in 1976.

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DUTCH ELM DISEASE CONTROL: PERFORMANCE AND COSTS

ABSTRACT

Municipal programs to suppress Dutch elm disease have had highly variable results. Performance as measured by tree mortality was unrelated to control strategies. Costs for control programs were 37 to 76 percent less than costs without control programs in the 15-year time-span of the study. Only those municipalities that conducted a high-performance program could be expected to retain 75 percent of their elms for more than 20 to 25 years. Communities that experienced the fewest elm losses had a well founded program, applied it conscientiously and sustained their efforts over the years.

"Nature's noblest vegetable" is what the French botanist André Michaux (1746-1802) called the American elm.

SAVING THE ELMS has been a community goal in many of our cities and towns. Some communities are meeting that goal; some are holding their own; some have failed. In many areas highly-valued American elm trees have been virtually eliminated by Dutch elm disease. The methods of disease control have been aimed at blocking the transmission of the fungus to healthy elms by elm bark beetles and through root grafts between diseased and healthy elms.

To find out how well Dutch elm disease control programs are working, we gathered and analyzed public records of control performance and costs for 39 municipalities, many of them in the Midwest, where Dutch elm disease is less likely to be confounded by elm losses due to phloem necrosis. The municipalities studied ranged in population from 3,000 to 1,500,000 and had elm trees ranging in numbers from 2,000 to 50,000.

The records available ranged in time span from 5 years to 18 years. The information reported was: (1) the total number of elm trees in the city or in the control program, (2) the number of elms contracting Dutch elm disease each year, (3) the control measures specified, and (4) the costs of the control program.

Additional data were taken from published sources *(Neely 1967 and 1972, and Neely and others 1960)*.

We combined all these records and other information to find out how well the control measures were keeping the Dutch elm disease within manageable proportions. Community performance in Dutch elm disease control was judged by how successful the community was in saving its elms, and the financial consequences of the control program.

Control Strategies

Control measures can be classified on a technological basis into three major strategies:

Strategy	*Vector control measures*
1. Reduce bark beetle habitat.	Sanitation (prompt removal of infested elms and pruning of infested branches).
2. Reduce bark beetle habitat and control beetle population.	Sanitation and use of insecticide to further reduce beetle population and reduce transmission of the disease.
3. Reduce bark beetle habitat, control beetle population, and prevent tranmission through root grafts.	Sanitation, use of insecticide, and injection of chemicals into soil to prevent transmission through root grafts.

Even though they are technically logical, these strategies cannot be used as a basis for rating performance. We first combined data from different municipalities according to these strategies, expecting to find that those municipalities that had followed strategy 3 got better performance than those that followed strategies 1 or 2. Performance data were measured in number of trees becoming infected each year per 1,000 original elms.

Contrary to our expectations, we found that there was no correlation between performance and strategy. A municipality that sustained a particular level of performance

under one strategy (strategy 2) performed similarly when it switched strategies (to strategy 1 or strategy 3). These technological strategies are mere labels, and we question if such labels are relevant to control performance. Good performers (municipalities with a low incidence of Dutch elm disease) did a better job whatever strategy they followed, if the strategy was appropriate to their local situation — that is, tree spacing, disease incidence, factors affecting the beetles, etc.

Control Performance

We grouped municipalities into classes based on sustained control performance. We labeled these:

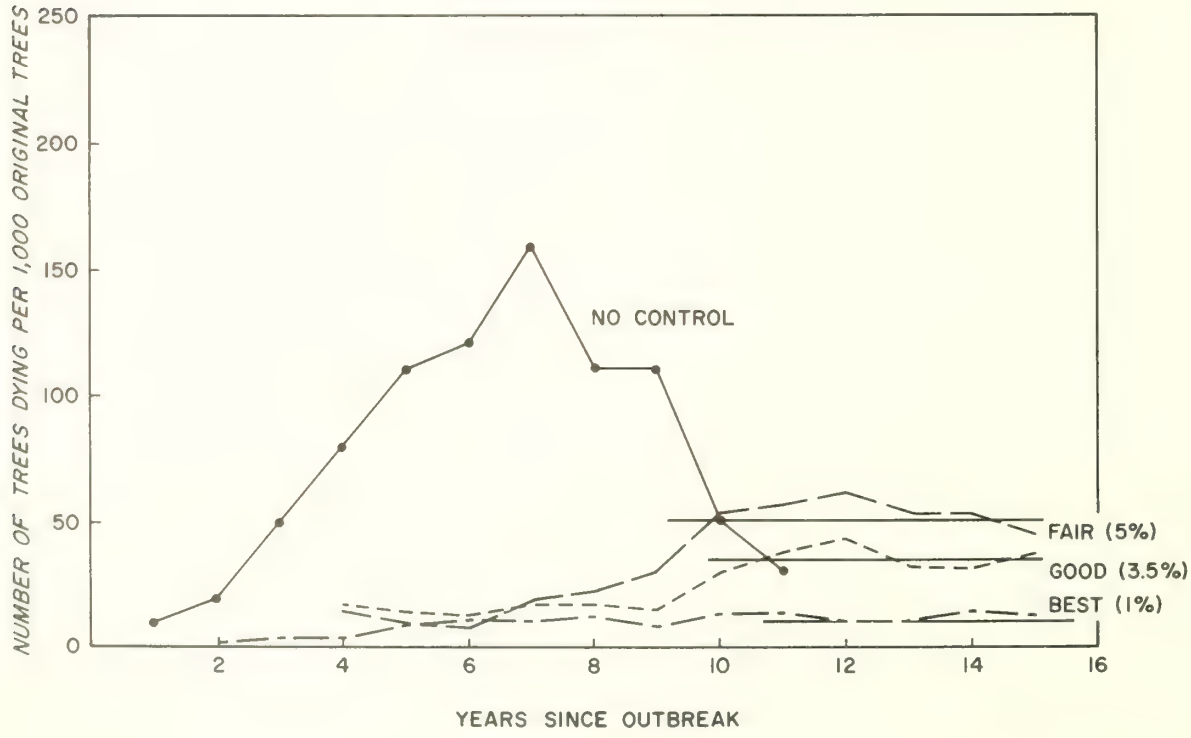
1. Best performance — those municipalities that have an elm mortality of about 1 percent of the original elms per year.
2. Good performance—those municipalities that had a mortality rate of no more than 3.5 percent per year.
3. Fair performance — those municipalities that had a mortality rate of no more than 5 percent per year.
4. No control.

The records of these groups of municipalities were contrasted with those that had no control programs (fig. 1).

To understand the reasons for differences in control performance, we talked to researchers and others in the control business, we read many accounts of how Dutch elm disease progressed in different cities, and we devised a list of reasons for the differences in performance.

Biological reasons.—1. Different spacing of elms call for different control measures. For example, a municipality in which elms are closely clumped together couldn't attain a high performance without root-graft control, whereas a municipality in which elms are widely distributed wouldn't need it. 2. Different physical distributions of elms alter the probability of their contracting the dis-

Figure 1.—Number of trees expected to die each year under each of four control-program performance levels.



ease. For example, elms could be so widely dispersed and such a small part of the total shade-tree population that transmission of the disease by root grafts would be minimal.

Operational reasons.—1. Lack of leadership in the community and failure to understand the gravity of the situation (*Gunderson 1964*). 2. Lack of money. 3. A mixture of authorities, each of which is responsible for a certain group of elms, all operating within different priorities or budget constraints so that their work is inconsistent with a total control program. 4. Group conflicts within the community government or among influential organizations. 5. Lack of effective authority to treat or remove privately owned elms, so that islands of disease elms are left for prolonged periods. 6. Crews in the field who do not conduct their work carefully and conscientiously, and a management that does not allow enough time to do a good job.

Of course, not all of these factors are present in any one municipality, and there could be other ones that are paramount in particular communities. One factor that seems to be of concern in most communities is the privately-owned diseased elm and the community's lack of authority to remove it promptly.

If a community is to have an effective disease-control program, it must plan and study carefully to make sure that it develops a program based on biological conditions. And no matter how good a program is, it will not succeed unless it is carried out vigorously and conscientiously under a unified authority that has the power to compel action.

Control Costs

Different municipalities account for costs differently. We could not relate performance data to cost of control programs. To do so would have required on-site cost studies. The information we brought together was not suitable for a rigorous breakdown of performance against cost. In fact, both good performers and poor performers had a similar range of costs for individual jobs and for the total control program. Some excellent performances seemed very economical while some poor performances seemed very expensive. The costs we did collect in 1972 have been updated to 1979 (table 1) with the Producer Price Index by the method described in the appendix.

Save-the-elms Evaluation

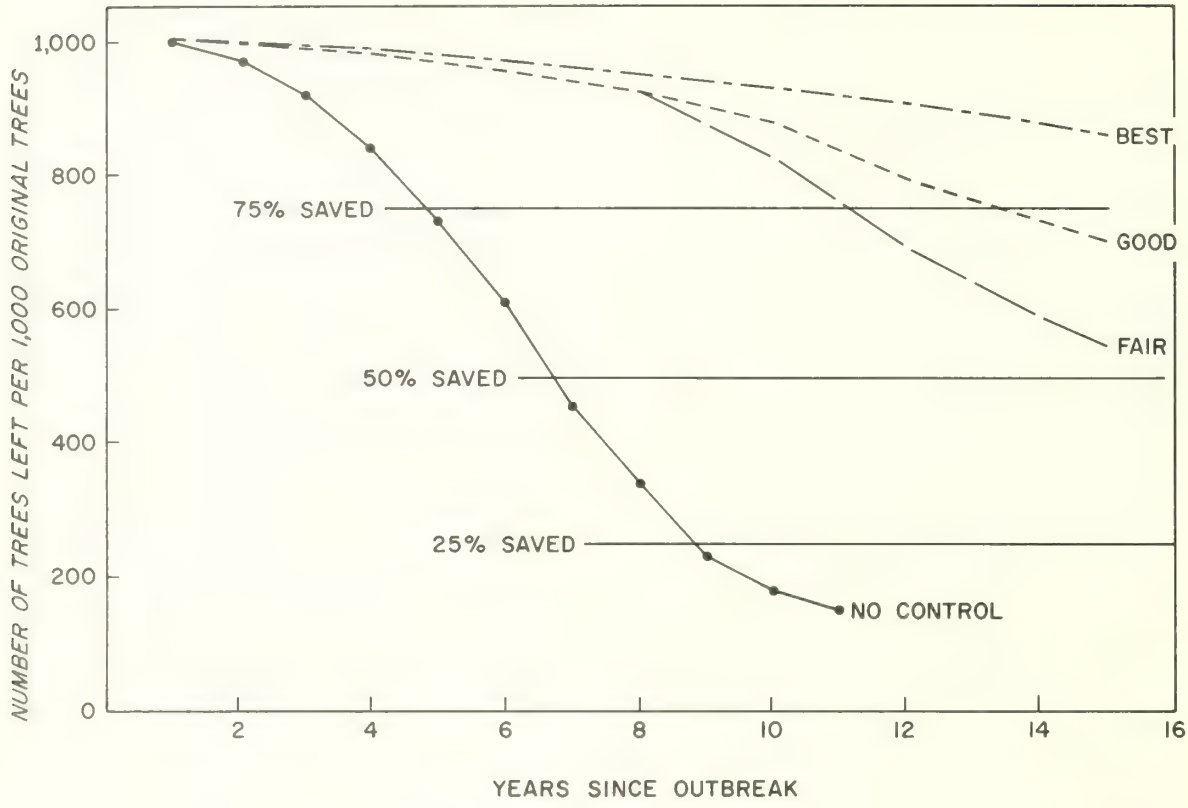
Most communities engaging in a Dutch elm disease control program would like to save as many elms as possible for as long as possible. What do these control performances mean in terms of *save-the-elms*?

For example, we might select *75 percent saved* as a goal. All but the best performance level will allow the elm population to fall below this goal in the 15-year time frame of the study (fig. 2). Without any control, the population of elm trees would drop to the 75-percent level in about 5 years. With the fair and good levels, it would take 11 and 13 years respectively. But with the best

Table 1.—1979 costs of individual jobs comprising the municipal Dutch elm disease control program

Job	Units	Cost	
		Range	Average
Tree removal	Per tree removed	$100.00-425.00	$215.00
Sanitation	Per tree in population	1.70- 3.50	2.50
	Per tree sanitized	26.00- 70.00	40.00
Spraying	Per tree in population	0.85- 1.20	1.00
	Per tree sprayed	2.60- 4.75	3.50
Root-graft control	Per tree treated		8.50
Survey for symptoms	Per tree in population	0.25- 0.50	0.35

Figure 2.—Length of time in which save-the-elms goals can be achieved with different control-program performance levels.



control, it would take 25 to 27 years to drop the population to the 75 percent level.

Of course, if we were willing to use a goal of 50 percent saved, our time frames would be greatly expanded (table 2).

Table 2.—Years before the elm population is reduced to various percentages of the original number of elms by following any one of four municipal performances

Performance class	Years to reduce elm populations to designated levels of the original elms[a]	
	75% Level	50% Level
No control	5	7
Fair control	11	(16-18)
Good control	13	(20-22)
Best control	(25-27)	(44-48)

[a]Estimates in parentheses are extrapolated, assuming continuation of the recorded trends.

Financial Consequences

Most municipalities operate on a budget basis rather than on an investment basis. In our financial evaluation, we did not use a discount rate to conform to budgets. We used our cost data (table 1) and our performances data (fig. 1) to develop a 15-year budget for three alternative courses of action.

1. Tree removal with no control, an estimate of the cost of doing nothing.
2. Tree removal with fair control, using the higher costs from the cost range (table 1). This gives us an estimate of the highest average costs to be expected from an active control program.
3. Tree removal with the best control performance, using the lowest costs from the cost range. This gives us an estimate of the lowest average costs to be expected from an active control program.

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1980. **Dutch elm disease control: performance and costs.**
Northeast. For. Exp. St., Broomall, Pa.
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ODC 305 + 355 + 12 × 1.401.50 + 443.3 -- 172.8 + 453 + 907.12

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The costs of active control measures were used to produce a band of costs rather than cost lines (fig. 3). We would expect that the costs to a community for undertaking a control program would fall inside this band of costs.

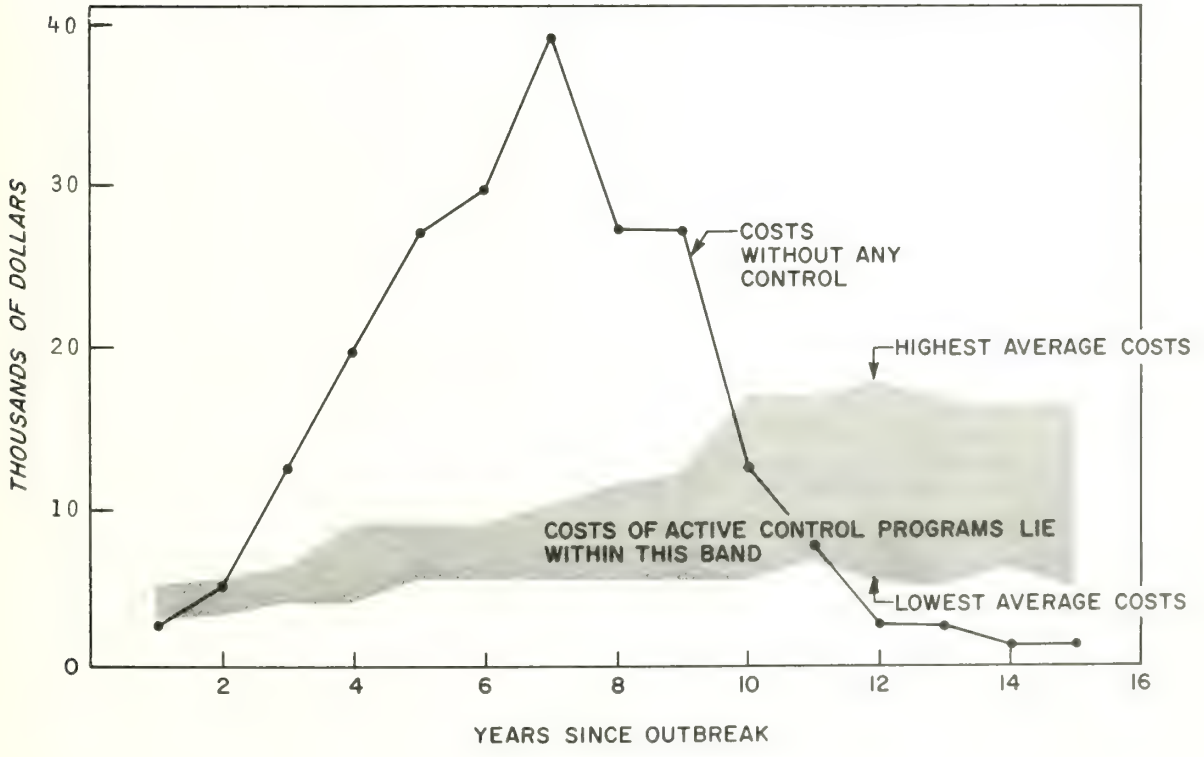
The costs of the no-control alternative rise spectacularly, peaking at about 7 years, then declining to well below the cost band for active control measures at about 12 years. At that time only 10 to 15 percent of the elms remain alive. Early active control efforts slow the increase in costs; and finally, in 5 to 10 years—depending on the efficiency of control—the costs will settle into fairly steady patterns. In 15 years we will still have 55 to 85 percent of the elms left alive, depending on control performance. The benefits of a control program are:

1. More time to enjoy our elms.
2. Fewer budget fluctuations.
3. Time for scientists to find better control measures.

By far the largest loss to the community where control is not undertaken is the reduction of property value associated with loss of shade trees. The minimum value of an elm tree is the cost of removing it, but most people would assign a higher value to it for such esthetic reasons as shade and beauty. Hart (*1965*), in a report on the economic impact of Dutch elm disease in Michigan, stated that the loss in esthetic value greatly overshadowed all other losses. In addition, there are losses of urban wildlife and changes in microclimates. In view of the difficulty in assigning a dollar value to these losses, we chose to use property-value losses since Payne and others (*1973*) suggested that shade, microclimatic, and esthetic benefits can be considered as they relate to residential property values. They indicated that a loss of $430 per tree was appropriate.

Summary costs and average annual costs for the 15-year period are given in table 3. Tree mortality was multiplied by $430 per

Figure 3.—Tree removal and control costs, based on a unit of 1,000 trees.



tree to estimate property loss. For the no-control alternatives, annual budget requirements for the peak year are 2.7 times the average budget requirements. Where positive control measures are taken, the peak budget requirements amount to 1.2 to 1.6 times the average.

Total loss during the 15-year period (table 3) includes the cost of control (table 1), disposal of dead and dying trees, and property value loss. If effort is made to remove elms before they become physical hazards, the budget requirements of a do-nothing program can exceed those of a control program, especially during the 12-year period after introduction of the disease. Larger losses of elms each year require greater personnel and equipment to deal with the situation. A recent development to reduce the costs of tree removal and disposal, and also reduce the volume of material going into sanitary landfills, is to sell the wood for lumber, pulpwood, and other useful products.

While we didn't consider replanting values in our costs, a tree-replanting program could lessen the impact of elm losses on property values in future years. One can hardly equate the esthetic and shade value of newly planted trees 2 to 3 inches in diameter with that of elms 20 to 30 inches or more in diameter, but replacement would eventually assure a stable tree population that would benefit the community.

We judged the effectiveness of the control program in terms of the budget figures and in terms of community values, which include property-value loss. The highest and lowest costs were subtracted from the no-control totals and expressed as savings in dollars and as a percentage of the no-control costs (table 3). The budget savings in control and disposal costs alone amounted to between $35,000 and $140,000 for our 1,000-tree unit or between 16 and 63 percent of the no-control option.

These savings were calculated at a zero discount rate as being relevant to a budget situation rather than an investment situa-

Table 3.—Economic impact of control measures for a 15-year period

Items of concern	Cost and performance for three alternatives, based on a 1,000-tree unit[a]		
	No control	Low performance: high cost control	High performance: low cost control
Status of elm population after 15 years:			
Dead (number)	880	438	133
Remaining (number)	120	562	867
Annual budget cost:			
Average (dollars)	15,200	12,800	5,700
Maximum (dollars)	41,400	20,500	7,000
Maximum increase above average: (dollars)	26,200	7,700	1,300
(percent)	173	60	23
Total loss + cost during the 15-year period:			
Cost of control and disposal (dollars)	227,000	192,000	84,000
Property value loss[b] (dollars)	379,000	189,000	59,000
Total cost + loss (dollars)	606,000	380,000	143,000
Effectiveness of control operation over the 15-year period:			
Savings in control and disposal costs: (dollars)		35,000	143,000
(percent)		16	63
Total savings: (dollars)		226,000	463,000
(percent)		37	76

[a] Based on 1979 dollars.
[b] Payne and others (1973).

tion. Had we calculated them with a positive discount rate, say 8 percent, the percentage savings would have been larger. The peak costs of the no-control option against which the active controls were compared would have been disproportionately greater. Our percentage savings on a budget basis are conservative.

Both Marsden (*1953*) and Sinclair and others (*1968*) proposed that the annual expenses of a control program might be substantially less than the expense of elm removals in the absence of a program. The experiences of the municipalities in our study bear this out (fig. 3). Of course, the annual cost of elm removals in a no-control program will decline as fewer and fewer elms remain to be infected with the disease. The additional cost of an active control program will, at that time, be protecting a substantial elm population (table 3).

The implication for managers in terms of budget requirements is that even the costliest control program would create less of an impact on the annual budget than the tree-removal costs of no control (fig. 3). If the disease were allowed to proceed unchecked, the annual budget requirements would rise sharply. This would probably disrupt the budget planning of most communities.

Summary and Discussion

The efforts made by municipalities to suppress Dutch elm disease have had highly variable results. Differences in performance could be traced to both biological and operational reasons. In many instances the operational difficulties outweighed the biological factors. We found that performance was not related to particular control strategies.

The budget costs of control programs were less than the costs of removing the large numbers of elms associated with the no-control alternative. Fluctuations in the annual budget were minimized, enabling managers to plan for the long pull and to maintain control performance. Total savings attributed to control programs ranged from 37 to 76 percent.

A community attempt to save the elms is greatly enhanced by an active control program. If we assume that a reasonable goal is to save 75 percent of the elms, the lack of an active control program will allow the elm population to sink below the goal in 5 years. An active program can extend this time by a factor of 3 to 5, depending on the level of control performance.

The quality and quantity of effort to apply control programs to limit Dutch elm disease inevitably reflects the interests and resources of local communities and their governing bodies. Some communities temporarily suspended control programs during a period of temporary financial stress only to find that they could not regain control of the disease situation later. Faced with increasing elm losses, and lacking the resources to substantially increase their control efforts, they found themselves with an ever worsening situation until few elms remained. The communities that experienced the fewest elm losses not only had well-founded control programs and applied them conscientiously, but sustained their efforts over the years.

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Appendix

We adjusted the 1972 cost data to January 1979 by dividing the 1979 producer price index (formerly the wholesale index) by the 1972 index to find the adjustment factor:

$$\frac{\text{1979 index}}{\text{1972 index}} = \frac{205}{119} = 1.723, \text{ the adjustment factor.}$$

The 1972 costs reported in the 1976 version of this paper were multiplied by 1.723 to update them to 1979.

This same method can be used to project costs into the future. First, estimate the expected rate of inflation. Then with this rate and the number of years over which the projection is to be made, find the adjustment factor in the body of the table. Suppose you expect the rate of inflation to be 10 percent per year over the next 2 years. The adjustment factor for the first year is found on line 1 in the column headed 10 percent; the factor for the second year is on line 2 in the same column. The cost next year would be 1.10 times the present cost; the cost 2 years hence would be 1.21 times the present cost.

Appendix Table 1.—Multipliers for updating costs.

Years	Percentage change in the price index						
	2	4	6	8	10	12	14
1	1.02	1.04	1.06	1.08	1.10	1.12	1.14
2	1.04	1.08	1.12	1.17	1.21	1.25	1.30
3	1.06	1.12	1.19	1.26	1.33	1.40	1.48
4	1.08	1.17	1.26	1.36	1.46	1.57	1.69
5	1.10	1.22	1.34	1.47	1.61	1.76	1.93
6	1.12	1.27	1.42	1.59	1.77	1.97	2.19
7	1.15	1.32	1.50	1.71	1.95	2.21	2.50
8	1.17	1.37	1.59	1.85	2.14	2.47	2.85
9	1.20	1.42	1.69	2.00	2.36	2.77	3.25
10	1.22	1.48	1.79	2.16	2.59	3.11	3.71

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TAPER-BASED SYSTEM FOR ESTIMATING STEM VOLUMES OF UPLAND OAKS

by Donald E. Hilt

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FOREST SERVICE RESEARCH PAPER NE-458
1980

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

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Abstract

A taper-based system for estimating stem volumes is developed for Central States upland oaks. Inside bark diameters up the stem are predicted as a function of dbh_{ib}, total height, and powers and relative height. A Fortran IV computer program, OAKVOL, is used to predict cubic and board-foot volumes to any desired merchantable top dib. Volumes of test trees were predicted with acceptable accuracy. Other uses for the taper-based system are discussed.

INTRODUCTION

NUMEROUS VOLUME TABLES for upland oaks have been constructed in past years. While most are satisfactory for the intended use, few provide the flexibility available with a taper-based system for estimating stem volumes. Users often desire predicted volumes to merchantable top diameters that differ from the published tables. A taper-based system allows the user to calculate volumes to any desired top diameter. Volume in any portion of the stem may also be calculated.

Some of the older volume tables constructed by the alignment chart method cannot be computerized because there is no prediction equation. Other volume tables based on regression equations sometimes fail to produce consistent trends between cubic volumes to various top diameters, or between board-foot and cubic-foot volumes. Logical and consistent trends result when a taper-based system is used.

This paper presents a taper-based system for estimating cubic and board-foot volumes of upland oaks. Diameter breast height inside bark (dbh_{ib}) and total tree height are required to estimate stem volumes with the taper-based system. Diameter breast height outside bark (dbh_{ob}), measured in the field, can be converted to dbh_{ib} using appropriate bark-thickness factors for each oak species. Total height may be measured in the field or estimated with a local height-diameter curve.

DATA

Felled-tree measurements were collected on 418 upland oak trees located in Ohio, Kentucky, Missouri, Indiana, and Illinois. Oak species were white oak (*Q. alba* L.), chestnut oak (*Q. prinus* L.), black oak (*Q. veluntina* Lam.), scarlet oak (*Q. coccinea* Muenchh.), and northern red oak (*Q. rubra* L.) Dbh_{ob} ranged from 2.4 to 25.5 inches and total height from 21 to 116 feet. A systematic sample of 334 trees was selected to develop the taper equation. The remaining 84 trees were used to validate the model (test data set one).

Dbh_{ob} was recorded for each standing tree. The trees were then felled and bucked into 6 to 20 sections. Height above ground and diameter inside bark (dib) were measured on each section. Dbh_{ib} was measured at the section point 4.5 feet above ground.

An additional 124 oak trees from West Virginia and Virginia were used as a second test data set. Each tree was bucked into nine sections and the dib and height above ground were recorded for each section. Dbh_{ob} ranged from 6.0 to 21.9 inches and total height from 48 to 104 feet.

ANALYSIS

Taper equation

The taper equation was constructed from tree measurements by using a modification of the taper model proposed by Bruce et al. (1968). The modified form of the equation is

$$y = x^{3/2} + \sum_{i=1}^{n} \sum_{j=0}^{1} \sum_{k=0}^{1} \beta_{ijk} \left(x^{3/2} - x^{j+1}\right) D^{i} H^{k} \qquad (1)$$

where

$y = d^2/D^2$

$x = (H-h)/(H-4.5)$

d = dib at measurement point (inches)

$D = dbh_{ib}$ (inches)

H = total tree height (feet)

h = height at measurement point (feet)

and the β's and γ's are constants to be determined. The equation satisfies the logical conditions that d equals zero when h equals H, and d equals D when h equals 4.5 feet. I used dbh_{ib} in the equation because bark thickness varies according to oak species. Dbh_{ob} can be converted to dbh_{ib} using appropriate bark-thickness factors for each species.

Note that the β's can be estimated by linear model procedures for given values of the γ's. I used a simplified version of equation (1),

$$y = x^{3/2} + \sum_{i=1}^{n} \beta_i (x^{3/2} - x\gamma i) \qquad (2)$$

to determine reasonable values for the γ's. Different values of the γ's were substituted into (2) by trial and error, and the resulting equation was fitted to the data with stepwise regression procedures (maximum R^2 improvement method) after each substitution. The values $\gamma_1 = 3$ and $\gamma_2 = 30$ suggested by Bruce proved to be satisfactory. Given these values for the γ's, stepwise regression procedures were then used to estimate the β's in equation (1). The resulting model was

$$\begin{aligned}\hat{y} = x^{3/2} &+ 3.04392(10^{-3})\,(x^{3/2} - x^{3})\,H \\ &+ 2.26030(10^{-4})\,(x^{3/2} - x^{3})\,DH \\ &+ 3.21012(10^{-3})\,(x^{3/2} - x^{30})\,D \\ &- 2.12000(10^{-4})\,(x^{3/2} - x^{30})\,DH\end{aligned} \qquad (3)$$

Inside bark diameters on the stem can be estimated from (3) as

$$\hat{d} = D\sqrt{\hat{y}} \qquad (4)$$

Equation (4) represents the average stem profile for trees of specified D and H. The calculated R^2 for the taper model based on residuals of the form $(\hat{d} - d)$ was 0.93. Typical curves shown in Figure 1 illustrate the reasonable taper curves, including butt flare, generated by equations (3) and (4) for upland oaks.

Cubic volumes

A form factor $(\hat{F})$ representing the ratio of cubic volume inside bark from tip to a given height (h*) on the stem, to a cylinder of diameter D and height (H - 4.5), can be computed by integrating (3):

$$\hat{F} = \int_0^z \hat{y}\, dx$$

$$\begin{aligned} &= 0.4\, z^{5/2} + 1.21752\,(10^{-3})\,(z^{5/2})\,H \\ &\quad - 7.6098\,(10^{-4})\,(z^{4})\,H \\ &\quad + 9.041\,(10^{-5})\,(z^{5/2})\,DH \\ &\quad - 5.651\,(10^{-5})\,(z^{4})\,DH \\ &\quad + 1.28405\,(10^{-3})\,(z^{5/2})\,D \\ &\quad - 1.0355\,(10^{-4})\,(z^{31})\,D \\ &\quad - 8.48\,(10^{-5})\,(z^{5/2})\,DH \\ &\quad + 6.84\,(10^{-6})\,(z^{31})\,DH \end{aligned} \qquad (5)$$

where

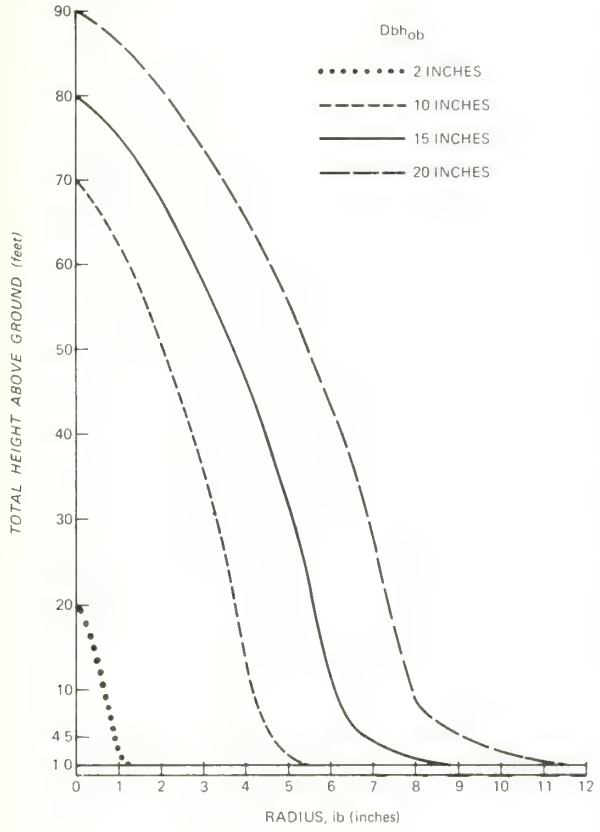
$$z = \frac{H - h^*}{H - 4.5}$$

Predicted cubic volume inside bark $(\hat{V})$ from tip to h* is then calculated as

$$\hat{V} = .00545415\, D^2\, (H-4.5)\, \hat{F}\,. \qquad (6)$$

Cubic volume of the stem from tip to a 1-foot stump (TOTVOL) was predicted with equations (5) and (6) using h* = 1.0. Merchantable cubic volumes from a 1.0-foot stump to merchantable top dib were predicted by setting h* equal to the height to merchantable top dib, then subtracting the resulting volume from TOTVOL. A stump volume equal to the volume of a cylinder 1 foot long and diameter equal to the predicted dib at 1 foot was added to TOTVOL to arrive at the predicted total stem cubic volume (CVTS).

Figure 1.—Stem profiles as estimated by equations (3) and (4). Constant dbh_{ib}/dbh_{ob} ratio = 0.91 used.



"Actual" cubic volumes of trees were calculated by summing the volumes of measured sections. The volume of each section was computed as a frustrum of a cone. Predicted volumes were then compared to the actual volumes for CVTS and cubic volume to a 4-inch top (CV4) (Table 1). The measured dbh_{ib} was used to predict volumes for the mode data set. Dbh_{ib} was calculated as 0.91 x dbh_{ob} for the two test data sets to simulate actual use of the equations because bark thickness is not usually measured in the field. The average percentage deviations and differences between total volumes were considered acceptable for the model data set, especially since the computation of actual volumes is certainly not exact. Excellent results were also obtained for the first test data set. The standard deviation of the precentage differences was approximately 10 percent in most cases. This value indicates that for a given tree, the CVTS or CV4 can be estimated with a ± 10 percent error. Total volume for all trees is estimated with more accuracy.

Predicted volumes were consistently low for the second test data set. Part of the reason for low estimates may be due to the constant dbh_{ib}/dbh_{ob} ratio of 0.91 that

Table 1.—Comparison of predicted and "actual" volumes

Data set[a]	No. of trees[b]	Average percentage differences[c]	Standard deviation of percentage differences	Total "actual" volume	Total predicted volume	Percentage difference, totals
Model:						
CVTS	334	1.1	9.8	8861	8811	-0.6
CV4	187	1.8	10.6	7051	7005	-0.7
BF8	187	1.7	19.1	35816	34109	-4.8
Test 1:						
CVTS	84	1.8	10.0	2310	2309	0
CV4	49	2.2	9.9	1883	1881	-0.1
BF8	49	0.7	19.1	9577	9274	-3.2
Test 2:						
CVTS	124	-6.9	8.5	3471	3205	-7.7
CV4	59	-5.6	9.0	2643	2452	-7.2
BF8	59	-9.4	15.5	13916	12342	-11.3

[a]CVTS = cubic volume total stem, ib; CV4 = cubic volume to 4-inch top, ib; BF8 = International 1/4-inch rule board-foot volume to 8-inch top.

[b]CVTS analyzed for all trees; CV4 and BF8 for trees 11.6 inches dbh_{ob} and larger.

[c]Percentage difference = [(predicted volume — actual volume)/actual volume] x 100.

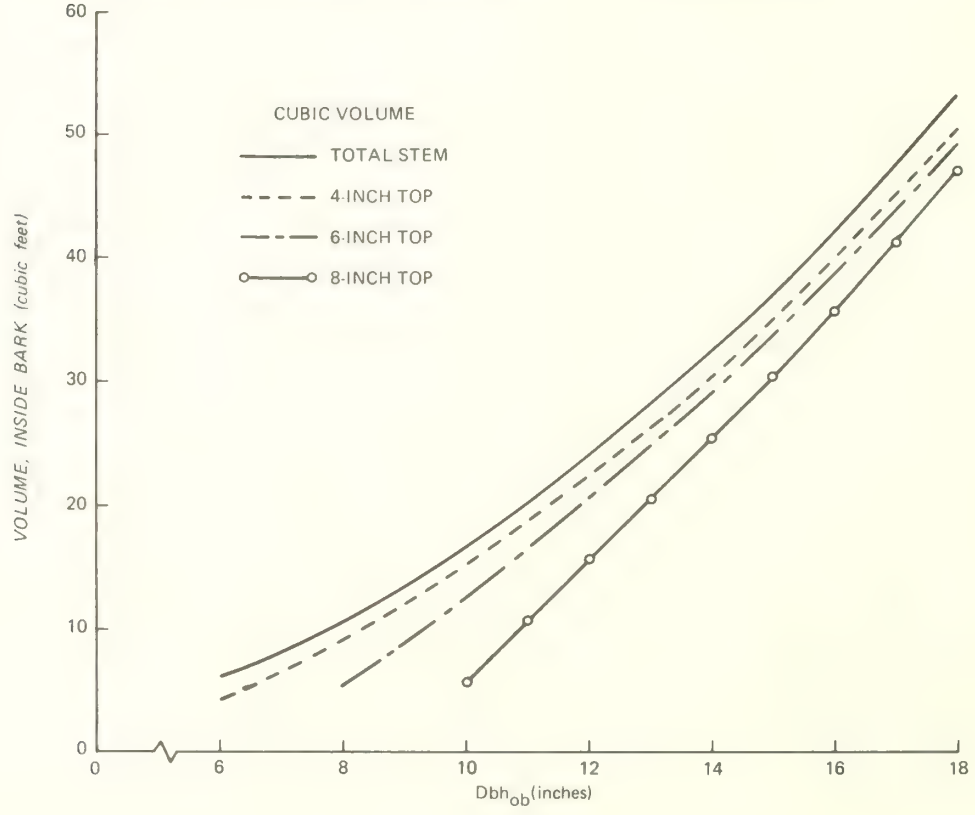
was applied. The main reason was because the stem form of the trees from West Virginia and Virginia was much better than the stem form of the trees used to build the taper equation. The average of the stem form factors predicted with equation (5) using $h^* = 1.0$ was 0.472, while the actual stem form averaged 0.509. If the sample of 124 trees provide a good representation of all trees found in West Virginia and Virginia, then the taper equation constructed in this paper for Central States upland oaks would not be applicable and the construction of an appropriate taper system for this geographical region is recommended. If the sample of well-formed trees occurred by chance, as the case may be occasionally for Central States upland oaks, then the predicted volumes can be adjusted by using methods proposed by Gevorkiantz (1955).

Cubic volumes to various merchantable top diameters are shown in Figure 2 for a tree 80 feet tall. The volumes generated from equations (5) and (6) form smooth and logical progressions with increasing dbh_{ob}. Trends were similar for other height classes.

Board-foot volumes

International 1/4-inch rule board-foot volumes were calculated for all trees 11.6 inches dbh_{ob}. and larger. Total board-foot volume (BF8) in the tree was determined by summing the board-foot volumes of all logs in the tree to an 8-inch top. Allowance was made for a 1.0-foot stump and 0.3 feet of trim for each 16-foot log. Fractional 16-foot log lengths at the top of the tree were calculated by 4-foot sections, including fractional length on the remaining 4-foot section. Predicted board-foot volumes were computed using scaling diameters estimated with equations (3) and (4). Actual board-

Figure 2.—Cubic volumes to 8-, 6-, 4-inch tops, and total stem for 80-foot total height tree.



foot volumes were computed using measured or interpolated scaling diameters.

A comparison of actual and predicted board-foot volumes is shown in Table 1. Average percentage deviations and differences between total values were acceptable for the model data set and the first test data set. The standard deviation of the percentage differences, 19.1 in both cases, is larger than it is for cubic volumes. This larger value should be expected because estimation of board-foot volumes in trees requires the estimation of several scaling diameters up the stem. Considering the variability that occurs in many upland oak stems, the results are excellent.

Estimates for the second test data set are low for board-foot volumes, just as they were for cubic volumes. Predicted board-foot volumes may also be adjusted according to methods proposed by Gevorkiantz (1955).

Board-foot/cubic-foot ratios were plotted for various heights and diameters (Figure 3). The ratios follow smooth and logical trends.

Program OAKVOL

The taper-based volume equations presented in this paper are too complex to be solved easily with a desk calculator. A Fortran IV computer program titled OAKVOL (Appendix) was written to provide the flexibility desired when using the taper-based system. The four subroutines provide the necessary programing logic for applying the taper-based system to a variety of uses. Explanation of each subroutine may be found in the program listing. The main program was written to allow the user to specify any number of fixed merchantable top diameters for both cubic and board-foot volumes. Modification of the main program, and possibly the subroutines, is necessary depending on the intended use.

Figure 3.—International 1/4-inch board-foot/total stem cubic volume ratios.

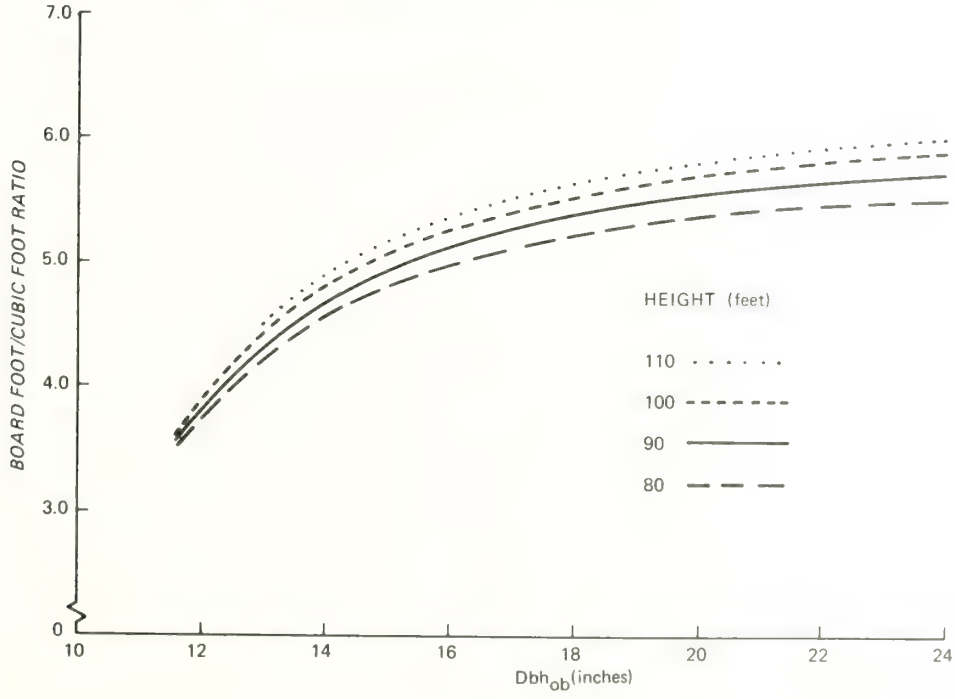


Table 2.—Sample total cubic-foot volume table [a]

Diameter breast high, ob (inches)	Total height (*feet*)										
	20	30	40	50	60	70	80	90	100	110	120
2	.236	.290	.36	—	—	—	—	—	—	—	—
3	.559	.662	.82	.99	—	—	—	—	—	—	—
4	—	1.194	1.46	1.76	2.1	—	—	—	—	—	—
5	—	1.893	2.30	2.75	3.2	3.7	—	—	—	—	—
6	—	—	3.3	4.0	4.6	5.3	6.0	6.7	—	—	—
7	—	—	4.6	5.4	6.3	7.3	8.2	9.2	—	—	—
8	—	—	6.0	7.1	8.3	9.5	10.7	11.9	—	—	—
9	—	—	7.6	9.0	10.5	12.0	13.5	15.0	16.6	—	—
10	—	—	9.5	11.2	12.9	14.8	16.6	18.5	20.4	—	—
11	—	—	—	13.6	15.7	17.9	20.1	22.3	24.5	26.7	—
12	—	—	—	16.2	18.7	21.2	23.8	26.4	29.1	31.7	—
13	—	—	—	19.0	21.9	24.9	27.9	30.9	33.9	36.9	—
14	—	—	—	22.1	25.5	28.9	32.3	35.7	39.2	42.6	—
15	—	—	—	25.5	29.2	33.1	37.0	40.9	44.8	48.6	—
16	—	—	—	—	33.3	37.6	42.0	46.3	50.7	55.0	59.3
17	—	—	—	—	37.6	42.4	47.3	52.1	56.9	61.7	66.5
18	—	—	—	—	42.2	47.5	52.9	58.2	63.5	68.8	74.0
19	—	—	—	—	47.1	52.9	58.8	64.6	70.5	76.2	81.8
20	—	—	—	—	52.2	58.6	65.0	71.4	78.4	83.9	90.0
21	—	—	—	—	—	64.6	71.5	78.4	85.2	91.9	98.5
22	—	—	—	—	—	70.8	78.3	85.8	93.1	100.3	107.3
23	—	—	—	—	—	77.3	85.4	93.4	101.3	108.9	116.4
24	—	—	—	—	—	84.1	92.8	101.3	109.7	117.9	125.8
25	—	—	—	—	—	91.2	100.4	109.6	118.5	127.1	135.5

[a]Cubic volume of entire stem, less bark. Includes 1.0-foot stump volume. Constant dbh_{ib}/dbh_{ob} ratio = 0.91 used.

Table 3.—Sample board-foot volume table [a]

Diameter breast high,ob (inches)	Total height (feet)							
	50	60	70	80	90	100	110	120
12	53	65	77	90	101	112	124	—
13	69	85	102	118	134	150	166	—
14	85	105	127	147	168	188	208	—
15	102	126	153	177	202	227	251	—
16	—	149	180	208	238	267	295	323
17	—	173	208	241	276	308	341	373
18	—	198	237	276	314	351	388	424
19	—	224	266	312	354	396	437	477
20	—	251	298	349	395	443	488	532
21	—	—	332	388	438	491	539	588
22	—	—	367	428	484	541	593	647
23	—	—	404	469	531	592	649	706
24	—	—	442	511	579	644	707	767
25	—	—	482	555	630	698	766	829

[a]International 1/4-inch rule board-foot volumes to 8-inch top dib. Allowance made for 1.0-foot stump, 0.3 feet trim for each 16-foot log, and fractional length on upper log. Constant dbh_{ib}/dbh_{ob} ratio = 0.91 used.

59.3
66.5
74.0
81.8
90.0

98.5
07.3
16.4
25.8

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542.11, 524.15, 524.2, 524.315

ywords: Computer program

Even though a large number of computations are necessary to calculate volumes using OAKVOL, the cost is very reasonable. In a sample run, CVTS was calculated for 33,600 trees and BF8 for 11,628 trees in 38 seconds on an AMDAHL 470V/6 computer. Computing could be simplified by fitting regression equations to explain relationships such as those shown in Figure 2 and 3. However, most users have access to high-speed computers, and should prefer the flexibility available with OAKVOL.

Sample volume tables generated with OAKVOL for CVTS and BF8 are shown in Table 2 and 3. A constant dbh_{ib}/dbh_{ob} ratio of 0.91 was used to determine dbh_{ib}. In practice, a variable ratio according to the oak species should be used.

DISCUSSION

The inherent flexibility of a taper-based system allows compatible cubic and board-foot volumes to be calculated to any desired top diameter. Modification of OAKVOL will allow users to apply the system to a variety of other uses. Percentage distributions of volumes within trees, often desired for biomass and whole-tree chipping studies, can be conveniently computed with a taper-based system. Stem surface areas, ib, can also be calculated. The easiest method for computing surface areas would be to segment the "stem" into a finite number of sections (100 should be adequate), then calculate the surface area for each section with the formula for a truncated cone.

Volume tables based on the number of logs to variable top diameters, often desired for timber cruising, can also be constructed using the taper-based system. Field measurements would require dbh_{ob}, total height, and number of 16-foot logs to the variable merchantable top dib. Total height could be estimated using a local height-diameter relationship. After converting the number of logs to a merchantable height, volumes could be computed using a modified version of OAKVOL.

The taper-based system developed in this paper should be useful to many foresters working in the upland oak timber type. High-speed computers permit inexpensive applications of the system.

LITERATURE CITED

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APPENDIX

```
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXC
C                                                                                                      C
C     PROGRAM OAKVOL                                          WRITTEN BY D.HILT, 1979                  C
C                                                                                                      C
C                                                                                                      C
C     CUBIC FOOT AND BOARD FOOT (INTERNATIONAL 1/4-INCH RULE) VOLUMES                                  C
C     CAN BE CALCULATED TO VARIOUS MERCHANTABLE INSIDE BARK DIAMETERS                                  C
C     USING THE SUBROUTINES PRESENTED IN THIS PROGRAM. THE MAIN PROGRAM                                C
C     MUST BE MODIFIED BY EACH INDIVIDUAL USER TO FACILITATE THE                                       C
C     DESIRED INPUT AND OUTPUT. THE PROGRAM PRESENTED HERE ALLOWS A                                    C
C     VARIABLE NUMBER OF MERCHANTABLE INSIDE BARK DIAMETERS TO BE                                      C
C     SPECIFIED.                                                                                       C
C                                                                                                      C
C     TREES MUST BE LARGER THAN 1.9 INCHES DBHOB AND TALLER THAN 20 FEET.                              C
C                                                                                                      C
CXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXC
C                                                                                                      C
C                                                                                                      C
C     --- DIMENSION ARRAYS ---                                                                         C
C                                                                                                      C
      IMPLICIT REAL*8 (A-H,O-Z)
      INTEGER CVTOPS,BFTOPS,TREENO
      REAL*8 (CVDIBS(10),CVHTS(10),CUVOLS(10)/10*0./,BFDIBS(10),
     1BFHTS(10),BFVOLS(10)/10*0./,DBHOIB(10),TOPHTS(10)
C                                                                                                      C
C                                                                                                      C
C     --- SPECIFY NUMBER OF MERCHANTABLE TOP DIBS TO BE USED                                           C
C     CVTOPS = NUMBER OF CUBIC VOLUME MERCHANTABLE TOP DIBS                                            C
C     BFTOPS = NUMBER OF BOARD FOOT MERCHANTABLE TOP DIBS                                              C
C          IF CVTOPS = 0, THEN NO CUBIC VOLUMES WILL BE CALCULATED                                     C
C          IF BFTOPS = 0, THEN NO BOARD FOOT VOLUMES WILL BE CALCULATED ---                            C
C                                                                                                      C
      CVTOPS=2
      BFTOPS=2
C                                                                                                      C
C     --- SPECIFY MERCHANTABLE TOP DIBS WITH DATA STATEMENT. LIST IN                                   C
C         DECENDING ORDER ---                                                                          C
C                                                                                                      C
      DATA CVDIBS/4.,6.,.../
C                                                                                                      C
C     --- IN THIS EXAMPLE CUBIC VOLUMES INSIDE BARK TO A 4-INCH TOP,                                   C
C         AND TOTAL STEM WILL BE CALCULATED. BOARD FOOT VOLUMES TO                                     C
C         8- AND 6-INCH TOPS WILL BE CALCULATED ---                                                    C
C                                                                                                      C
C                                                                                                      C
C*************************************************************************************************C
C
C
C     --- READ TREE DBHOB AND TOTAL HEIGHT.
C         ALL READ AND WRITE STATEMENTS IN THIS PROGRAM ARE FOR SAMPLE
C         PROBLEM ONLY. IF NEEDED BY THE USER, THEY MUST BE MODIFIED ---
    5 READ(5,10,END=20)DBHOB,HT
   10 FORMAT(11S,F5.1,3X,F5.1)

C
C     --- CALCULATE DBHIB. (CONSTANT DBTIB/DBHOB RATIO = .91 ASSUMED
C         FOR THIS EXAMPLE ---
      DBHIB=DBHOB*.91
C
C     --- CALL SUBROUTINES TO CALCULATE VOLUMES
      IF(CVTOPS.EQ.0)GO TO 20
      CALL BISECT(DBHIB,HT,CVTOPS,CVDIBS,CVHTS)
      CALL CUVOL(DBHIB,HT,CVTOPS,CVHTS,CUVOLS)
   20 IF(BFTOPS.EQ.0)GO TO 30
      CALL BISECT(DBHIB,HT,BFTOPS,BFDIBS,BFHTS)
      CALL BFVOL(DBHIB,HT,BFTOPS,BFDIBS,BFHTS,BFVOLS)
```

```
C
   30 WRITE(6,2)DBHOB,HT,(CUVOLS(I),I=1,CVTOPS),(BFVOLS(I),I=1,BFTOPS)
    2 FORMAT(T10,8F8.2)
      GO TO 5
  200 STOP
      END


      SUBROUTINE BISECT(DBHIB,HT,NTOPS,TOPDIB,TOPHTS)
C
C     --- THIS SUBROUTINE USES A BISECTION ALGORITHM (ITERATIVE
C         APPROACH) TO DETERMINE THE LENGTHS (TOPHTS) FROM TIP TO THE
C         DESIRED MERCHANTABLE INSIDE BARK DIAMETERS (TOPDIB) ---
C
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 TOPDIB(10),TOPHTS(10)
      A=0.0
      B=HT-1.0
      D=0.0
      ZMDIB=0.0
      DO 10 I=1,NTOPS
      K=I
      IF(TOPDIB(I).LT..01)GO TO 55
      Z=HT-1.0
      CALL DIB(DBHIB,HT,Z,D)
      IF(D.LE.TOPDIB(I))GO TO 40
      DO 20 J=1,50
      ZMIDPT=(A+B)/2.
      CALL DIB(DBHIB,HT,ZMIDPT,ZMDIB)
      DIFF=TOPDIB(I)-ZMDIB
      IF(DABS(DIFF).LT..01)GO TO 45
      IF(DIFF.LT.0.)GO TO 50
      A=ZMIDPT
      GO TO 20
   50 B=ZMIDPT
   20 CONTINUE
   40 TOPHTS(I)=HT-1.0
      GO TO 10
   45 TOPHTS(I)=ZMIDPT

      A=0.0
   10 CONTINUE
      GO TO 60
   55 TOPHTS(K)=0.0
   60 RETURN
      END

      SUBROUTINE DIB(DBHIB,HT,ZHT,ZDIB)
C
C     --- THIS SUBROUTINE CALCULATES THE DIB (ZDIB) AT A
C         GIVEN LENGTH FROM THE TIP (ZHT)
C
      IMPLICIT REAL*8 (A-H,O-Z)
      Z=ZHT/(HT-4.5)
      X1=Z**1.5
      X2=X1-Z**3
      X3=X1-Z**90
      X4=X2*HT
      X5=X3*DBHIB
      X6=X5*HT
      X7=X4*DBHIB
      ZDIB=X1+(.04*X4-.3*X5-.1*X6+.2*X7)/(X1+.04*X4-.3*X5-.1*X6+.2*X7)
     1*X7
      ZDIB=DBHIB*(ZDIB)
      RETURN
      END
```

```
      SUBROUTINE CUVOL(DBHIB,HT,NTOPS,TOPHTS,CUVOLS)
C
C     --- THIS SUBROUTINE CALCULATES CUBIC VOLUMES (CUVOLS) TO
C         DESIRED MERCHANTABLE INSIDE BARK DIAMETERS.
C         TOPHTS = DISTANCE FROM TIP TO MERCHANTABLE HEIGHT ---
C
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 TOPHTS(10),CUVOLS(10)
      L=0
    5 DO 50 I=1,NTOPS
      K=I
      IF(TOPHTS(I).LT..001)GO TO 55
      IF(L.EQ.1)GO TO 10
      Z=TOPHTS(I)/(HT-4.5)
   10 X1=Z**2.5
      X2=Z**4
      X3=Z**31
      X4=X1*HT
      X5=X2*HT
      X6=X4*DBHIB
      X7=X5*DBHIB
      X8=X1*DBHIB
      X9=X3*DBHIB
      X10=X9*HT
      F=.4*X1
      F=F+(1.21757D-3)*X4
      F=F-(7.6098D-4)*X5
      F=F+(9.041D-5)*X6
      F=F-(5.651D-5)**7
      F=F+(1.28405D-3)*X8
      F=F-(1.0355D-4)*X9
      F=F-(8.48D-5)*X6
      F=F+(6.84D-6)*X10
      IF(L.EQ.1)GO TO 60
      CUVOLS(I)=.00545415*DBHIB*DBHIB*(HT-4.5)*F
   50 CONTINUE
      GO TO 57
   55 CUVOLS(K)=0.0
   57 Z=(HT-1.0)/(HT-4.5)
      L=1
      GO TO 5
   60 TOTVOL=.00545415*DBHIB*DBHIB*(HT-4.5)*F
C
C     --- CALCULATE 1.0 FOOT STUMP VOLUME ---
      STUMPH=HT-1.0
      CALL DIB(DBHIB,HT,STUMPH,STUMPD)
      STUMPV=.00545415*STUMPD*STUMPD
C
C     --- CALCULATE CUBIC VOLUMES TO MERCHANTABLE TOP DIAMETERS ---
      DO 70 I=1,NTOPS
      CUVOLS(I)=TOTVOL-CUVOLS(I)
      IF(TOPHTS(I).LT..001)CUVOLS(I)=TOTVOL+STUMPV
   70 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE BFVOL(DBHIB,HT,NTOPS,BFDIBS,TOPHTS,BFVOLS)
C
C     --- THIS SUBROUTINE CALCULATES INT'L 1/4 INCH RULE BOARD
C         FOOT VOLUMES (BFVOLS) TO DESIRED MERCHANTABLE INSIDE BARK
C         DIAMETERS (BFDIBS). TOPHTS = DISTANCE FROM TIP TO MERCHANTABLE
C         HEIGHT ---
C
      IMPLICIT REAL*8 (A-H,O-Z)
      REAL*8 TOPHTS(10),BFVOLS(10),BFDIBS(10),LOGDIB
      LOGDIB=0.0
      DO 90 I=1,NTOPS
      TOPHTS(I)=HT-TOPHTS(I)
      H=1.0
      BFVOLS(I)=0.
   50 H=H+.3
      IF(H.GE.TOPHTS(I))GO TO 90
      H=H+16.
      IF(H.GT.TOPHTS(I))GO TO 55
      Z=HT-H
      CALL DIB(DBHIB,HT,Z,LOGDIB)
      BFVOLS(I)=BFVOLS(I)+.796*LOGDIB*LOGDIB-1.37*LOGDIB-1.23
      GO TO 50
   55 H=H-16.
      A=TOPHTS(I)-H
      ILOG4=A/4.
      LOGDIB=BFDIBS(I)
      IF(ILOG4.EQ.0)GO TO 65
      DO 60 J=1,ILOG4
      BFVOLS(I)=BFVOLS(I)+.199*LOGDIB*LOGDIB-.642*LOGDIB
      LOGDIB=LOGDIB+.5
   60 CONTINUE
   65 FRAC=(A-(FLOAT(ILOG4)*4.))/4.
      BFVOLS(I)=BFVOLS(I)+(.199*LOGDIB*LOGDIB-.642*LOGDIB)*FRAC
   90 CONTINUE
      RETURN
      END
```

VOLUMES GENERATED FOR FIVE SAMPLE TREES:

DBH_{OB}	TOTAL HEIGHT	CV4	CVTS	BF8	BF6
10.0	67	12.89	14.22	27.08	53.98
11.7	74	19.68	21.18	74.07	94.67
13.3	83	28.39	30.13	131.81	149.07
15.2	92	40.66	42.74	214.22	227.81
18.0	87	53.89	56.64	303.18	309.51

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Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

- Amherst, Massachusetts, in cooperation with the University of Massachusetts.
- Beltsville, Maryland.
- Berea, Kentucky, in cooperation with Berea College.
- Burlington, Vermont, in cooperation with the University of Vermont.
- Delaware, Ohio.
- Durham, New Hampshire, in cooperation with the University of New Hampshire.
- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.

Figure 2.—Regression curves for the ratio of the weight of an age class of foliage to the weight of foliage the same age and older on a branch by foliage age and whorl age. The letter labels for each curve indicate the sampling location (H = New Hampshire, B = New Brunswick) while the number labels indicate foliage age.

the model both as an exponential and a linear term. The flowering effect term in the exponent reduced the sum of squares only slightly, and was dropped from the model. The linear term reduced the sum of squares by 8 percent over the model using whorl number and needle age. Needle age was also added to adjust the asymptote in the model and improved the fit by 14 percent. The remaining branch and tree variables only marginally reduced the residual sum of squares. Thus, the foliage age-class ratio model is:

$$P_{ia} = b + 0.858e^{(-0.265\,(N_{ij}) + 0.236(a))} + 0.075e^{(0.220(a))} \text{ for } a < N_{ij} \quad (5)$$

$$= 1.0 \text{ for } a = N_{ij}$$

where

P_{ia} = ratio of foliage weight in age class (a) to weight of foliage the same age and older on a branch from i^{th} whorl

N_{ij} = age of the i^{th} whorl on the j^{th} tree

b = 0.038 for nonflowering years and

= -0.012 for flowering years.

The model had an R^2 of 0.91 for the 968 sets of measurements.

Foliage weight by age

The branch total foliage weight and the foliage age-class ratio estimates can be used to predict foliage weight by age class on a given whorl. The predicted 1-year-old foliage ratio

from equation (5) is multiplied by the predicted branch total foliage weight from equation (4) to estimate the weight of 1-year-old foliage on a branch. The remaining foliage weight is calculated by subtracting the predicted 1-year-old foliage from the predicted total foliage weight. Similarly the 2-year-old foliage ratio is estimated from equation (5) and multiplied by the remaining branch foliage weight to predict the weight of 2-year-old foliage. This process is continued until the weight of foliage in five age classes is estimated for a branch on a given whorl.

The procedure for predicting the weight of age (a) foliage on a branch from whorl (i) can be written as:

$$W_{ia} = P_{ia}\left[\prod_{k=1}^{a-1}\left(1 - P_{ik}\right)\right] W_i \qquad (6)$$

where

W_i = the total weight of foliage on a branch from the i^{th} whorl

and

$\prod_{k=1}^{a-1}$ symbolizes the product of the (a–1) variables within the parenthesis.

Total foliage weight per branch and the remaining foliage weight after calculating W_{ia} for each whorl and foliage age is depicted for a typical balsam fir in Figure 3.

DISCUSSION

A series of equations was developed to estimate (a) the normal weight of foliage on

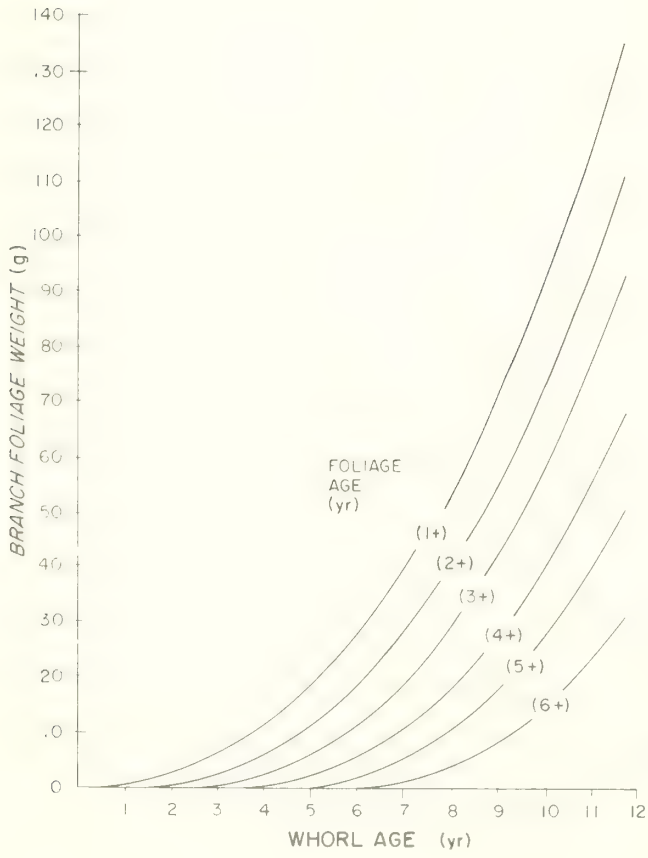

Figure 3.—The predicted weight of foliage for a given age and older on a branch from each whorl for the top half of a 45-year-old balsam fir (DBH = 14 cm; crown length = 7.0 m; 24 whorls in the crown; flowering with foliage aged 2 and 4).

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THE QUALITY AND AVAILABILITY OF HARDWOOD LOGGING RESIDUE

Based on Developed Quality Levels

FOREST SERVICE RESEARCH PAPER NE-459
1980
FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

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Abstract

Hardwood logging residue was examined for salvageable quality material. Four quality levels (QL 1 to QL 4), based on four sets of specifications, were developed. The specifications used surface indicators, sweep, center decay, and piece size to determine quality. Twenty-six percent of the total logging residue (residue $\geq$ 4 inches in diameter outside bark at small end and $\geq$ 4 feet long, except if $\geq$ 2 feet long and $\geq$ 12 inches dob) from saw log only harvesting operations met the lowest of the four quality levels (QL 4). QL 4 could best be described as local use logs. The acceptability of residue at QL 4 increased to 36 percent if bolewood only was considered. Only 9 percent of the residue would be salvageable at the QL 1 level.

INTRODUCTION

FOREST MANAGERS are increasingly interested in achieving greater timber utilization. Logging residues are a major concern because of the large volumes generated annually. In West Virginia, for example, Martin (1975a) estimated that timber harvesting operations produce approximately 80 million cubic feet of residue per year. This is in material equal to or larger than 4 inches in diameter outside bark (dob) and 4 feet or longer.

Logging residue protects the site and acts as a nutrient bank for forest soil, and provides wildlife with shelter and food. While these are important uses, we may be approaching the time when some residue can be used commercially in lieu of harvested trees.

The feasibility of using logging residue depends on two factors: (1) the physical suitability of residue wood for different product uses; and (2) the value of products derived from residues versus the cost of recovery and processing. In 1977, I evaluated logging residue as a raw material for producing mine timbers (Timson 1978). The study on which this report is based was concerned with the suitability of residue wood where the physical requirements for acceptance were more stringent than the quality requirements for mine timbers.

Logging residue has become an accepted term, but what it encompasses depends on specific situations. Logging residue as used or referred to in this report is felled or knocked over material remaining on the site after a harvesting operation (see cover).

QUALITY LEVELS

In the mine timber study, hardwood logging residue was examined to find what percentage of the material remaining after a saw log only cutting operation was suitable for a specific product. For this study, no specific product requirements were used. Rather, four sets of specifications (quality levels) were developed to classify the residue wood.

The reason for the switch from studying residue from a specific to a general standpoint was the lack of even minimum specifications for raw materials used in making a given product. Through the use of the four quality specifications, a more general knowledge of residue quality could be obtained.

Potential users of the findings of this study can compare their raw material specifications with the quality levels used here. The readers' specification and quality levels of the study probably will not compare exactly. However, the reader can interpolate where his specifications lie among the four quality levels and interpolate approximately the percent of a given logging residue source that can be used in his specific case.

The quality levels (QL 1, 2, 3, 4) include two length classes, each containing two quality standards.

QL 1

Length: 4 to 5 feet.
Minimum diameter: 8 inches.
Surface: 2 or more clear faces full length of piece.
Defect indicators (other faces):
Seam—Acceptable if it can be confined to face edge.
Knots, bumps, etc.—diameter not to exceed face width.
Sweep: None.
Unsound end defects: ≤ 12-inches (dob)—none allowed.
> 12 inches (dob)—allowed in center one-third of end diameter.

QL 2

Length: 4 to 5 feet.
Minimum diameter: 6 inches.
Surface: 2 or more faces with at least one clear cutting each.
Minimum length cutting—24 inches.
Defect indicators:
Seam—acceptable if it can be confined to face edge.
Knots, bumps, etc.—diameter not to exceed face width.
Sweep: None.
Unsound end defects: ≤ 12 inches (dob)—none allowed.
> 12 inches (dob)—allowed in center one-half of end diameter.

QL 3

Length: 6 to 16 feet.
Minimum diameter: 8 inches.
Surface (second poorest face):
Minimum proportion clear—one-half.
Minimum length cutting—24 inches.
Maximum number cuttings—none.
Defect indicators:
Seam—acceptable if it can be confined to face edge.
Knots, bumps, etc.—diameter not to exceed face width.
Sweep: Absolute sweep, one-fourth of small end diameter.
Unsound end defects: ≤ 12 inches (dob)—none allowed.
> 12 inches (dob)—allowed in center one-fourth of end diameter.

QL 4

Length: 6 to 16 feet.
Minimum diameter: 6 inches.
Surface (second poorest face):
Minimum proportion clear—
6 to 8 feet, one cutting.
8.5 to 16 feet, two cuttings.
Minimum length cutting—24 inches.
Maximum number cuttings—none.
Defect indicators:
Seam—acceptable if it can be confined to face edge.
Knots, bumps, etc.—diameter not to exceed face width.
Sweep: Absolute sweep, one-fourth of small end diameter.
Unsound end defects: ≤ 12 inches (dob)—none allowed.
13 to 18 inches (dob)—allowed in center one-fourth of end diameter.
> 18 inches (dob)—allowed in center one-half of end diameter.

The QL specifications were not designed to meet a specified grading system. However, to help familiarize you with the specifications, the following comparisons can be made:

QL 1: The specifications are very close to those for Pennsylvania bolt grade 2 (Dunmire and others 1974). The most noticeable difference is that QL 1 has a lower diameter limit.

QL 2: This class is poorer in most respects than Pennsylvania bolt grade 3.

QL 3: This class is similar to factory grade 3 (Ostrander and others 1965). Minimum diameter and minimum length are less than grade 3 specifications.

QL 4: This is basically a local use log (Ostrander and others 1965) except that minimum diameter and minimum length do not meet minimum local use requirements.

THE STUDY

Logging residue was measured on 25 randomly selected areas within the Appalachian hardwood forest region (Fig. 1): 17 sample areas in West Virginia, 1 in Virginia, and 7 in Pennsylvania. Over 90 percent of the cutting sites were on private lands.

The selected areas had been cut for saw logs only. The cutting system used was a selection cut based on diameter limit, marked timber, or in some cases, the timber cutter's judgment.

One 1/2-acre circular plot was established on each sample area. In selecting plots, the field crew considered access, ease of identifying and measuring the residue (Fig. 2), and whether the volume of residue was sufficient to justify selecting that plot. Generally, we required at least 300 cubic feet of residue per acre to justify a given plot selection. However, very large concentrations of residue were avoided because of the difficulty in measuring and identifying the quality of individual pieces.

Figure 2.—The remains of a hardwood saw log cutting operation

Figure 1.—Locations of selected areas for residue measurement

These selection criteria were suitable for the study since the objective was to determine the percentage of residue that would meet the quality level requirements. Because of the plot selection method, unbiased volume per acre estimates cannot be developed.

Within each plot, pieces of residue that met the following standards were measured:

- Equal to or greater than 4 feet long
- Equal to or greater than 4 inches in diameter outside bark (dob) small end
- Equal to or greater than 2 feet long if small end exceeded 12 inches in diameter
- Lie within plot boundary or pieces that had any portion crossing one-half of the plot boundary circumference (0° to 180°)—

pieces crossing the remainder of the boundary were ignored

It should be noted that sweep (crookedness), rot, or any external characteristics did not exclude any piece from being measured as part of the total residue.

For each piece of residue, the following was recorded:

- Species
- Position in tree
  Bolewood—main stem to a 4-inch outside bark (ob) top or to where the stem breaks up
  Limbwood—to a 4-inch (ob) small diameter
- Large and small end dob—to nearest 1/2 inch
- Length—to nearest 1/2 foot

After the above information was recorded, the same residue was reexamined to determine the parts of each piece that could be classified as being acceptable for one or more of the QL classes. For each section of residue acceptable by a QL class, the following was recorded:

- QL class
- Species
- Position in tree (description given above)
- Large and small end dob—to nearest 1/2 inch
- Length—to nearest 1/2 foot

In classifying a portion of a piece of residue for a given QL class, the longest length acceptable was given first priority except where more of the overall piece of residue could be used by considering shorter lengths and more sections. Also, the residue on each plot was classified for each QL class independent of the other QL classes. It was possible for any given piece of residue to meet the specification for more than one QL class.

In the office, the piece measurement information (length and diameter) was used to calculate total volume, each QL class volume, and designated subclass volumes within the QL classes. The percentage of acceptable residue by QL class was then calculated by dividing each QL class volume by total volume. The same procedure was used to develop percentages by species, bolewood or limbwood, and various size classes for each QL specification.

RESULTS

Statistical analysis showed no difference between the southern (West Virginia, Virginia) and the northern (Pennsylvania) sample areas, so stratification was discarded. The percentage of residue that met each of the four quality levels is shown in Tables 1 through 4.

Nine percent of hardwood logging residue met QL 1 standards of which one-third could be cut into 5-foot lengths. Twenty-four percent of the residue met QL 2 standards, half of which would make 5-foot bolts.

In the longer QL classes, 14 percent of the logging residue met QL 3 specifications, and 26 percent was acceptable as QL 4 material. In both cases, approximately 60 percent of these amounts was in acceptable pieces over 8 feet long.

Limbwood accounted for 32 percent of the total saw log harvesting residue (Table 5), but produced only 0.4 to 2.1 percent of the total acceptable material. Considering acceptable residue from limbwood only, 1 percent met QL 1 and QL 3 standards, 4 percent met QL 4 requirements, and 7 percent was acceptable as QL 2 material.

Bolewood residue (the remaining 68 percent) was of considerably higher quality. Up to 36 percent of this material met at least one of the four QL requirements. In the short wood classes, 12 percent of the bolewood residue met QL 1 standards and 32 percent was acceptable in the QL 2 class. In the long wood classes, 19 percent of the bolewood residue met QL 3 specifications and 36 percent was suitable for the QL 4 class.

The amount of acceptable residue by species ranged from 3 percent to about 50 percent. Beech, followed by birch, had the smallest percentage of acceptable material. On the high end of the acceptability scale was basswood followed by hickory, the yellow-poplar/cucumber/magnolia group, and black cherry (Tables 1-4). The order of these species remained constant over all four QL

Text cont. on page 9

Table 1.—Percentage of logging residue useable at given quality levels and material measured (based on volumetric measure)

Quality Level 1

Species	Percent of measured residue useable at listed specs			Percent breakdown of quality level total			
	Total	4-ft lengths	5-ft lengths	Portion of QL 4 ft	Portion of 4 ft ≤ 10 in	Portion of QL 5 ft	Portion of 5 ft ≤ 10 in
				MATERIAL MEASURED—ALL			
Basswood	31	10	21	32	47	68	31
Hickory	16	11	5	71	39	29	38
Yellow-poplar/cucumber/ magnolia	12	6	6	47	33	53	54
Black cherry	10	8	2	83	59	17	72
Sugar maple	10	8	2	74	15	26	5
Red oak	8	6	2	73	45	27	57
Other hardwood	6	4	2	61	57	39	22
White oak	5	4	1	85	80	15	100
Red maple	4	4	0	88	11	12	100
Birch	4	4	0	100	0	0	0
Beech	3	2	1	58	26	42	14
All	9	6	3	64	36	36	40
				MATERIAL MEASURED—BOLEWOOD			
Basswood	37	12	25	32	47	68	31
Hickory	21	15	6	71	39	29	38
Yellow-poplar/cucumber/ magnolia	15	7	8	47	33	53	54
Black cherry	14	11	3	82	53	18	72
Sugar maple	16	12	4	74	15	26	5
Red oak	12	9	3	75	42	25	51
Other hardwood	10	6	4	57	50	43	22
White oak	6	5	1	84	77	16	100
Red maple	5	4	1	86	13	14	100
Birch	5	5	0	100	0	0	0
Beech	3	2	1	56	34	44	0
All	12	8	4	64	35	36	39

Table 2.—Percentage of logging residue useable at given quality levels and material measured (based on volumetric measure)

Quality Level 2

Species	Percent of measured residue useable at listed specs			Percent breakdown of quality level total			
	Total	4-ft lengths	5-ft lengths	Portion of QL 4 ft	Portion of 4 ft ≤ 10 in	Portion of QL 5 ft	Portion of 5 ft ≤ 10 in
				MATERIAL MEASURED—ALL			
Basswood	46	17	29	36	68	64	42
Hickory	36	20	16	55	39	45	74
Yellow-poplar/cucumber/ magnolia	36	16	20	44	50	56	66
Black cherry	33	18	15	56	67	44	68
Sugar maple	22	13	9	58	25	42	16
Red oak	24	12	12	50	66	50	66
Other hardwood	16	8	8	51	77	49	79
White oak	25	14	11	56	90	44	64
Red maple	16	10	6	62	39	38	69
Birch	13	11	2	81	11	19	100
Beech	11	5	6	44	47	56	41
All	24	12	12	51	52	49	58
				MATERIAL MEASURED—BOLEWOOD			
Basswood	53	20	33	37	68	63	41
Hickory	44	24	20	54	32	46	72
Yellow-poplar/cucumber/ magnolia	43	19	24	43	48	57	65
Black cherry	45	25	20	56	63	44	64
Sugar maple	30	17	13	56	20	44	15
Red oak	36	17	19	48	62	52	63
Other hardwood	25	12	13	48	72	52	74
White oak	33	19	14	59	89	41	56
Red maple	21	13	8	61	40	39	67
Birch	16	13	3	81	11	19	100
Beech	13	5	8	39	36	61	34
All	32	16	16	50	49	50	55

Timson, Floyd G.

1980. **The quality and availability of hardwood logging residue based on developed quality levels.** Northeast. For. Exp. Stn., Broomall, Pa.
10 p., illus. (USDA For. Serv. Res. Pap. NE-459)

Hardwood logging residue was examined for salvageable quality material. Four quality levels (QL 1 to QL 4), based on four sets of specifications, were developed. The specifications used surface indicators, sweep, center decay, and piece size to determine quality. Twenty-six percent of the total logging residue (residue ≥ 4 inches in diameter outside bark at small end and ≥ 4 feet long, except if ≥ 2 feet long and ≥ 12 inches dob) from saw log only harvesting operations met the lowest of the four quality levels (QL 4). QL 4 could best be described as local use logs. The acceptability of residue at QL 4 increased to 36 percent if bolewood only was considered. Only 9 percent of the residue would be salvageable at the QL 1 level.

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Keywords: Slash utilization, logging waste

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Keywords: Slash utilization, logging waste

Table 3.—Percentage of logging residue useable at given quality levels and material measured (based on volumetric measure)

Quality Level 3

Species	Percent of measured residue useable at listed specs			Percent breakdown of quality level total			
	Total	6-to 8-ft lengths	8.5-to 16-ft lengths	Portion of QL—6 to 8 ft	Portion of 6 to 8 ft ≤ 10 in	Portion of QL—8.5 to 16 ft	Portion of 8.5 to 16 ft < 10 in
				MATERIAL MEASURED—ALL			
Basswood	29	7	22	24	62	76	59
Hickory	26	12	14	45	23	55	50
Yellow-poplar/cucumber/ magnolia	21	7	14	33	62	67	63
Black cherry	21	8	13	40	60	60	69
Sugar maple	15	7	8	48	15	52	31
Red oak	12	6	6	47	55	53	53
Other hardwood	13	4	9	33	73	67	37
White oak	12	6	6	48	74	52	100
Red maple	7	2	5	23	22	77	57
Birch	8	3	5	35	100	65	0
Beech	4	2	2	37	49	63	0
All	14	6	8	39	47	61	52
				MATERIAL MEASURED—BOLEWOOD			
Basswood	35	8	27	24	62	76	59
Hickory	34	15	19	45	23	55	50
Yellow-poplar/cucumber/ magnolia	26	8	18	32	60	68	63
Black cherry	29	12	17	40	57	60	65
Sugar maple	22	10	12	47	11	53	31
Red oak	21	10	11	46	53	54	53
Other hardwood	20	5	15	27	64	73	37
White oak	18	9	9	50	74	50	74
Red maple	9	2	7	19	0	81	57
Birch	9	3	6	35	100	65	0
Beech	5	1	4	29	26	71	0
All	19	7	12	38	44	62	52

Table 4.—Percentage of logging residue useable at given quality levels and material measured (based on volumetric measure)

Quality Level 4

Species	Percent of measured residue useable at listed specs			Percent breakdown of quality level total			
	Total	6-to 8-ft lengths	8.5-to 16-ft lengths	Portion of QL—6 to 8 ft	Portion of 6 to 8 ft ≤ 10 in	Portion of QL—8.5 to 16 ft	Portion of 8.5 to 16 ft ≤ 10 in
				MATERIAL MEASURED—ALL			
Basswood	39	12	27	31	78	69	58
Hickory	38	19	19	50	45	50	64
Yellow-poplar/cucumber/ magnolia	36	12	24	34	55	66	69
Black cherry	34	13	21	39	69	61	76
Sugar maple	22	11	11	49	25	51	39
Red oak	25	14	11	56	67	44	71
Other hardwood	18	5	13	28	83	72	59
White oak	29	21	8	71	81	29	100
Red maple	32	8	24	26	57	74	25
Birch	15	9	6	58	46	42	24
Beech	11	6	5	57	42	43	48
All	26	11	15	44	57	56	57
				MATERIAL MEASURED—BOLEWOOD			
Basswood	46	14	32	31	78	69	58
Hickory	49	23	26	47	46	53	64
Yellow-poplar/cucumber/ magnolia	43	14	29	33	53	67	69
Black cherry	46	18	28	39	65	61	74
Sugar maple	31	14	17	46	20	54	39
Red oak	40	21	19	53	64	47	71
Other hardwood	30	8	22	26	76	74	60
White oak	43	30	13	69	80	31	100
Red maple	44	11	33	24	25	76	25
Birch	19	11	8	58	46	42	24
Beech	15	8	7	54	35	46	48
All	36	15	21	42	54	58	57

classes when all material was considered. When bolewood only was considered, there was a slight shifting of rank with different QL classes.

Table 5.—Percentage of bolewood and limbwood in Appalachian logging residue

Species	Bolewood	Limbwood
Basswood	85	15
Birch	81	19
Yellow-poplar/cucumber/ magnolia	81	19
Hickory	75	25
Red maple	73	27
Beech	68	32
Sugar maple	66	34
Black cherry	66	34
White oak	65	35
Red oak	59	41
Other hardwood	46	54
All	68	32

VOLUMES PER ACRE

Martin (1975a) reported that logging residue averaged 467 cubic feet to the acre. The areas measured included both clear and selection cuts for harvesting saw logs only or saw logs plus other products. In a followup study, Martin (1975b) found an average of 500 cubic feet per acre from 40 cutover areas (range: 90 to 2,600).

In the study of residues for mine timber production (Timson 1978), the areas sampled were selectively cut for saw log only harvesting operations. I found residue volumes ranging from 216 to 997 cubic feet per acre. Average volume per acre was 540 cubic feet. Total residue volumes on the current study plots averaged 657 cubic feet per acre (this is not necessarily representative of present volume due to plot selection method).

Therefore, if we use 500 cubic feet per acre as the total volume of residue left after a saw log only cutting operation, we can estimate the quality level yield for an average acre:

Quality class	Volume available from:	
	Total residue	Bolewood only
	$ft^3/acre$	
1	45	41
2	120	109
3	70	65
4	130	122

Or, if we assume that each cubic foot of QL 1 through QL 4 wood would yield 5.5 board feet of sawed product, we can estimate the QL board-foot yield:

Quality class	Volume available from:	
	Total residue	Bolewood only
	fbm/acre	
1	247	225
2	660	599
3	385	357
4	715	671

CONCLUSION

The amount of saw log harvesting residues that meets the specifications used in this study is limited. The least restrictive of the quality levels specified in this report allows material that is best described as "local use." Even at this level, 74 percent of the logging residue was unacceptable. Eighty-six percent would not meet factory grade 3 standards (similar to QL 3), and 91 percent would not be good enough for QL 1 specifications. Salvaging this class of material would require working through or around at least three times as much volume as could be recovered. Even if bolewood only is harvested, limbwood must be handled (Fig. 3).

Considering other sources that could supply the same product (Grade 3 lumber, trees removed in timber stand improvement, etc.) and taking into account the cost of handling, hardwood residue is not competitive. When cost, damage to the residual stand, competitive sources of supply, and material demand are considered, hardwood logging residue can best be used when extracted in the primary

Figure 3.—Large volume—little quality

harvesting operation and used for bulk products. The uses that come to mind are energy wood, chips, and pulpwood. There is another option for some of the residue—recycling in place.

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by G. W. Wendel and W. J. Gabriel

SUGAR MAPLE PROVENANCE STUDY:
West Virginia Outplanting—10-Year Results

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Abstract

After 10 years, survival of sugar maple (*Acer saccharum* Marsh.) provenances outplanted in West Virginia did not differ significantly. Total height, height growth and dbh measurements were significantly different among provenances. Fifty percent of the trees had major forks below 9.0 feet. Thirty-eight percent of the trees had no forks but 71 percent of these were in the intermediate or overtopped crown class. Forking was not related to provenance. Latitude, longitude, and elevation of provenances were not strongly correlated with provenance performance.

In 1968, a sugar maple provenance study was established on the Fernow Experimental Forest near Parsons, West Virginia. Seeds were collected from seven or eight parent trees in each of 15 provenances except for the West Virginia provenance, which was represented by two wildlings selected on each block. The seedlings were grown for 2 years in a nursery at Burlington, Vermont, and then outplanted at various locations in the Northeast.

The West Virginia outplanting (Fig. 1) was established on a cutover hardwood area at an elevation of 2,800 feet. The area has an easterly aspect and is relatively level (5 percent slope). The soil is DeKalb channery silt loam. Oak site index for the area is 75. Average precipitation on the Fernow Experimental Forest is 58 inches, mean annual temperature is 48° F, and the average growing season is 145 days.

The experimental design is a randomized complete block consisting of five rectangular blocks with their long dimensions parallel with the contour of the study area. Seedlings were planted at a 5- x 5-foot spacing. Each parent-provenance source is represented by a two-tree row plot in each block. During the first 6 years of outplanting, competing vegetation was controlled by hand mowing each summer.

Six-year results were reported by Wendel and Gabriel (1974). This paper reports height, diameter at breast height (dbh), crown position, and height to first major fork measurements taken at 10 years.

Figure 1.—Sugar maple provenance study plantation at 10 years

RESULTS

Survival

Survival averaged 93 percent for the first 10 years. There was no significant difference in survival among blocks or provenances. Except for the West Virginia source, all of the 15 provenances originated from higher latitudes than the planting site (Table 1). Thus, latitudinal differences in survival among provenances have been masked to a certain extent because the elevation of the planting site is 1,200 or more feet higher than the elevation of any of the provenances.

Total height

Average 10-year height for all provenances was 17.6 feet. The tallest trees in the plantation originated from seed collected in Chittenden County, Vermont. They averaged more than 20 feet and were 15 percent taller than the mean for all provenances (Table 2). Average height of trees from the Cass County, Minnesota, seed source was 14.7 feet, the lowest for all sources in the experiment.

The Spearman rank correlation coefficient between the 6-year total height ranking (Wendel and Gabriel 1974) and the 10-year ranking was 0.79. It was significant at the 1 percent level, indicating that the provenances with the tallest trees at 6 years in general have the tallest trees at 10 years. Thus, if we had selected the best performers at 6 years on the basis of total height, our selections at 10 years would be very similar.

There was a significant difference in total height among provenances at 10 years. However, further testing by the Newman-Keuls range test revealed no significant difference among the top nine provenances (Table 2). In contrast, the earlier published results (Wendel and Gabriel 1974) at 6 years showed that the top seven provenances did not differ significantly in total height. These results do indicate that there are possible genetic differences among provenances during the early years and that as time goes on some of the differences begin to fade out. Whether this trend will continue will have to be determined by future measurements.

Within provenance, differences in total height are showing change with time. At the end of six growing seasons, there was a significant difference in average height among progeny of parent trees within eight of the provenances, but at 10 years, average height was significant among families within only four of the provenances. Some of this change came from the death of small, overtopped trees and increased growth on other trees. Thus, trees in certain of the provenances seem better adapted to the outplanting site than others, suggesting genetic variation within provenances.

Table 1.—Sugar maple provenances represented in the West Virginia outplanting

Provenance number	County and state	Latitude	Longitude	Elevation (feet)
15	Ingham Co., Michigan	42° 45′	84° 30′	600-1,400
17	Berkshire Co., Mass.	42° 30′	73° 15′	1,500
18	Sullivan Co., N.H.	43° 27′	72° 23′	400
19	Addison Co., Vt.	43° 55′	72° 50′	900-1,000
20	Lewis Co., N.Y.	44° 00′	75° 23′	900
23	Franklin Co., Maine	44° 00′	70° 08′	560
28	Iron Co., Michigan	46° 15′	88° 33′	1,550
29	Quebec, Canada	46° 45′	71° 00′	350
31	Cass Co., Minn.	47° 15′	94° 30′	1,300
34	Mille Lacs Co., Minn.	46° 03′	93° 40′	1,300
35	Franklin Co., Vt.	44° 48′	72° 57′	600
36	Chittenden Co., Vt.	44° 29′	72° 53′	700-800
37	Rutland Co., Vt.	43° 27′	72° 54′	1,550-1,650
38	Bennington Co., Vt.	42° 57′	73° 10′	900-1,100
39	Tucker Co., W. Va.	39° 04′	79° 40′	2,800

Wendel, G.W. and W.J. Gabriel.
1980. **Sugar maple provenance study: West Virginia outplanting 10-year results.** Northeast. For. Exp. Stn., Broomall, Pa.
5 p., illus. (USDA For. Serv. Res. Pap. NE-46

After 10 years, survival of sugar maple (*Acer saccharum* Marsh provenances outplanted in West Virginia did not differ significantly. Tot height, height growth, and dbh measurements were significantly differe among provenances. Fifty percent of the trees had major forks below 9 feet. Thirty-eight percent of the trees had no forks but 71 percent of the were in the intermediate or overtopped crown class. Forking was n related to provenance. Latitude, longitude, and elevation of provenanc were not strongly correlated with provenance performance.

232.12 176.1 *Acer saccharum* Marsh.

Keywords: Survival; total height; height growth; diameter growth

Wendel, G.W. and W.J. Gabriel.
1980. **Sugar maple provenance study: West Virginia outplanting — 10-year results.** Northeast. For. Exp. Stn., Broomall, Pa.
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232.12 176.1 *Acer saccharum* Marsh.

Keywords: Survival; total height; height growth; diameter growth

Table 2.—Average total height, average 7- to 10-year height growth, and dbh for all sugar maple provenances

Geographic source	Average total height	Percent of mean height	7- to 10-yr height growth	Percent of mean 7- to 10-yr growth	10-yr dbh	Percent of mean 10-yr dbh
	Feet		*Feet*		*Inches*	
Chittenden Co., Vt.	20.3	115a	8.5	115a	2.2	122a
Lewis Co., N.Y.	19.6	111ab	7.9	107abc	2.1	117ab
Sullivan Co., N.H.	19.1	109ab	8.3	112ab	2.0	111ab
Rutland Co., Vt.	18.9	107ab	8.0	108ab	1.8	100abc
Iron Co., Mich.	18.2	103abc	8.0	108ab	1.7	94abc
Franklin Co., Vt.	18.0	102abc	7.4	100abcd	1.9	106abc
Addison Co., Vt.	17.7	101abc	7.5**	101abcd	1.9	106abc
Berkshire Co., Mass.	17.6	100abc	6.9	93abc	1.9	106abc
Ingham Co., Mich.	17.6	100abc	7.0	95abd	1.8	100abc
Quebec, Canada	17.2*	98bcd	7.2*	97abd	1.8	100abc
Bennington Co., Vt.	17.1*	97bcd	6.7*	91bcd	1.7	94abd
Tucker Co., W.Va.	16.6	94bcd	8.2	111ab	2.0	111ab
Franklin Co., Maine	15.7**	89cd	6.7*	91bcd	1.6	89bc
Mille Lacs Co., Minn.	15.3	87cd	6.4	86cd	1.4	78c
Cass Co., Minn.	14.7*	84d	6.1	82d	1.4	78c
Plantation average	17.6		7.4		1.8	

*Significant within provenance at 5 percent level.
**Significant within provenance at 1 percent level.
Numbers followed by the same letters do not differ significantly at the 5 percent level.

Height growth

The 7- to 10-year average height growth was significant among provenances and ranged from 6.1 to 8.5 feet (Table 2). Average annual growth for the period was 1.9 feet. It ranged from 2.1 feet for the fastest growing provenances to about 1.5 feet for the slowest growing.

The Chittenden County, Vermont, trees averaged 8.5 feet of growth during the 7- to 10-year period and this was about 15 percent better than the mean periodic growth for all provenances. Periodic height growth was lowest for the Cass County, Minnesota, trees (Table 2).

A comparison of provenance ranking by average height growth for the first 6 years of the study and for the current 7- to 10-year period yielded a Spearman's rank correlation coefficient of 0.48, indicating that there has been considerable change in height growth ranking among provenances during the two periods.

That growth differences among families within provenances are becoming less pronounced is evidenced by the fact that there was no significant difference in the 7- to 10-year height growth among 11 of the 15 provenances (Table 2). In 1973 at the end of the first 6 years, average height growth did not differ significantly among families in 8 of the 15 provenances.

Diameter growth

Ten-year average dbh ranged from 1.4 inches to 2.2 inches and averaged 1.8 inches for all provenances (Table 2). Trees originating from the Chittenden County, Vermont, sources averaged 22 percent larger than the mean for all provenances. The smallest trees were from the Cass County and Mille Lacs County, Minnesota, collections.

There was a significant difference in dbh among provenances. The overall diameter spread among provenances was 0.8 inch but for 12 of the 15 provenances, it was only 0.5 inch and these do not differ significantly when tested by the Newman-Keul's multiple range test. Thus, except for the two Minnesota and the Franklin County, Maine, proven-

ances, diameter growth does not differ greatly among provenances. This indicates that sources from most eastern and western parts of the sugar maple range are genetically not as well adapted to the conditions on the planting site as the other provenances.

The Spearman rank correlation coefficient between 10-year dbh and total height was 0.79, indicating that the trees with the largest diameters were also the tallest.

Forking

Many of the trees have major forks; the bole divides to form two stems of about equal height and diameter.

Thirty-eight percent of the trees have good form with no major forking (Table 3). However, 71 percent of these were in the intermediate or overtopped crown class and only 30 percent were dominant or codominant. Fifty percent of the trees had major forks between the ground and 9.0 feet, 12 percent forked between 9.1 and 17.0 feet, and less than 1 percent forked above 17.0 feet.

Forking was not related to provenance. Light browsing and some winter kill during the early years probably contributed to the incidence of forking. The frequent releases during the early life of the plantation may also have encouraged the development of more "bushy" trees. Normally sugar maple comes in as an understory tree and, in this situation, small trees grow slowly and the crowns tend to become sparse and flat-topped. Then, when the trees are released, a new leader assumes dominance and grows up through the flat top forming a straight, single stem (Trimble 1968).

At 10 years, the canopy of the study area is completely closed, and some of the forks may be shaded out. However, corrective pruning will have to be used on a large number of trees if stem quality is to be improved.

SUMMARY

After 10 growing seasons, survival among all provenances is still quite high. However, there are many low-vigor understory trees which will probably die during the next 5 or 10 years. With slightly more than 50 percent of the surviving seedlings in the intermediate and overtopped classes, the process of natural selection is in force and may very well result in the desired plantation density.

There were significant differences in average height, average height growth, and dbh among provenances at 10 years. Many of the differences are small, however, and they do indicate a strong similarity in reaction to the West Virginia environment by most of the provenances represented in the study. On the other hand, trees from the two most western and most eastern provenances were not doing well.

Height growth patterns among provenances have changed considerably with time. Rank correlation analyses showed a nonsignificant correlation between height growth rankings at the end of the first 6 years and the current 4 years, and yet total height correlation between ages 6 and 10 is high. The reason is that the increased growth rates have not yet brought about changes in total height. With this changing situtation, it is still too early to make judgments on provenance superiority.

Table 3.—Distribution of sugar maple trees by height to fork and by dominance class

Height to fork	Dominance Class				All
	Dominant	Codominant	Intermediate	Overtopped	
Feet	*Percent*				
0-9	11	18	10	11	50
9-17	3	5	3	1	12
17-25	<1	—	—	—	<1
No forks	4	7	9	18	38
All	18	30	22	30	100

At 10 years, there do not appear to be any strong correlations between total height or height growth and latitude, longitude, or elevation of parent tree sites. The outplanting site is at an elevation of 2,800 feet which is much higher than any of the provenance locations. Thus, differences among provenances that might have shown up have been masked by the elevation of the study area.

Forking is a problem on most of the study trees. Only 11 percent of the surviving dominant and codominant trees were free of forks. Most sugar maple stands originate from advanced sugar maple when stands are cut. Bushy, miltibranched trees such as many of those in the plantation are seldom found in natural stands. Even though the study trees were closely spaced 5 x 5 feet at planting time, annual releases permitted full sunlight on the trees up to 5 or 6 years. This open development during the early years may have stimulated the development of more bushy, branchy crowns which, in later years, produced the major forks that we are observing.

In general, the surviving dominant and codominant trees appear to be healthy and vigorous. Mortality up through 10 years has been low but, due to the large number of intermediate and overtopped trees in the plantation, we expect that mortality will increase in the next 5 to 10 years.

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Emotional Responses to Recreation Environments

by Thomas A. More

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Abstract

Recreation visits to natural areas are often supposed to result in a variety of unique emotional benefits for urban people. To test this, data on the moods of visitors to state parks, golf courses and museums were compared. The results indicated that (1) visitors arrived at all of the areas with moderate levels of positive moods and low levels of negative moods; (2) the levels of both positive and negative moods tended to decline during the experience; (3) while there were differences in moods between individual areas, it is not possible to attribute these differences solely to the type of recreation environment. Instead, there may be a process of anticipation and consummation that pervades recreation experiences and tends to outweigh differences between environments.

INTRODUCTION

URBAN FORESTS occupy a special place in the thinking of many people interested in conservation—both professionals and lay persons alike. However, advocates of these areas are often hard pressed to find arguments for preserving them in the face of changing land uses. Perhaps the most commonly cited argument is that recreation in natural areas near cities offers urban residents a variety of emotional and spiritual rewards to help them cope with the problems of modern urban life. Documentation of this is sparse, and nonbelievers are understandably skeptical.

What is the value of a walk in the woods or a family picnic in a natural area on a Sunday afternoon? How can it be measured? Might an alternative activity be substituted effectively? A number of approaches have evolved to deal with these questions (Driver et al. 1978), with varying degrees of success. One promising approach is measuring the emotional impact of recreational activities in terms of people's moods; different activities and environments might be expected to produce different kinds of feelings in people, providing a basis for the evaluation of recreation benefits.

As a construct, mood is defined as a class of feelings or emotions that are temporary and of relatively short duration, but fairly stable within that time period. Thus, a general feeling such as happiness, sadness, anxiety, affection, or anger may last for only a few minutes, several hours, or perhaps at most, a day or two. The very transience of a mood, however, makes it a good indicator of recreation quality—a high-quality experience should put people in a "good" mood, while the reverse should be true for a disappointing experience. However, the way in which this works is not quite so apparent. In a previous project, More and Payne (1978) found that visitors to day-use natural areas near cities arrived at the areas with moderately high levels of positive moods (surgency, elation, vigor, and social affection) and low levels of negative moods (aggression, anxiety, sadness, skepticism, and egotism). It was expected that during participation, the level of negative moods would decline, while the positive moods would rise. In actuality, however, the levels of both kinds of moods declined. To account for the decline in positive feelings, More and Payne postulated that once a decision to participate has been made, people look forward to participating and the levels of positive moods rise until they arrive at the site and begin participating. During participation, they consume the recreational activity until they reach a point where they tire of it and prefer to do something else. This satiation is accompanied by a decline in the level of positive moods.

This interpretation leaves a number of questions unanswered; perhaps chief among these is whether or not recreation in natural environments is unique in terms of its emotional impact on people. Rephrased in a broader context, the question might be: Do different recreation environments (ranging from outdoor to indoor) have different emotional effects or is the process just described a general one pervading all forms of recreation and overriding any differences? This question led to the formation of three general hypotheses for this study:

1. Participants in all the types of recreation studied were expected to begin participation with low levels of negative moods and moderate levels of positive moods.
2. The levels of both positive and negative moods would decline significantly during participation.
3. In spite of the volume of popular literature attributing special effects to outdoor recreation environments (McNamara 1971), there would be little difference between the moods of visitors participating in outdoor forest recreation activities, outdoor nonforest recreation activities, and indoor recreation activities.

METHODS

To test these hypotheses, visitors to four Massachusetts State Parks and Forests, two public golf courses, and two museums were interviewed during the summer of 1972. The four state forests and parks—Savoy State Forest, Mount Greylock State Reservation, Skinner State Park, and Hampton Ponds State Park—are located near cities in Western Massachusetts. Mount Greylock and Skinner offer picnicking and scenic vistas from mountain summits, while Savoy and Hampton Ponds offer swimming and picnicking. Although overnight camping is available at two of the areas, interviews were conducted only with day users. The two golf courses, Martin and Ponkapoag, are state operated and in Eastern Massachusetts; the museums—the Museum of Science and the New England Aquarium—are both in Boston.

At each area, a team of interviewers set up a checkpoint that enabled them to approach arriving visitors, asking them to participate in a survey. Those who agreed were given a self-administering questionnaire containing the Mood Adjective Checklist (MACL) developed by Nowlis (1965). The MACL uses 33 adjectives to measure 11 moods including aggression, anxiety, sadness, skepticism, egotism, surgency (cheerfulness), elation, vigor, social affection, fatigue, and concentration. Scores on each mood could range from 3 (very low) to 12 (very high).

As an instrument, the MACL—developed from a series of factor analytic studies—provides a gross but comprehensive index of a person's mood (Nowlis 1965). It seems to have good test-retest reliability when used in similar situations (Borgatta 1961, McNair and Lohr 1964). Although the adjectives differ in ratings of social desirability, these differences have little apparent effect on the actual responses given (Lazarus et al. 1972). In addition, the adjectives were probably equally socially desirable across the groups in this study so that between-group comparisons are not hampered. Finally, Handlon (1962) correlated one version of the MACL with physiological measures, but there are few other studies of this type.

As the respondents completed the MACL, the interviewer recorded sex, number in party, time, date, and weather conditions. Respondents were asked to initial the form so that their first interview could be matched with their second, and urged to return for a second interview when leaving. The second interview consisted of the MACL plus several socioeconomic questions. The interviewers again recorded time and weather.

This research design has three possible major sources of bias: bias introduced by a specific interviewer, bias created by the study design, and bias due to nonresponse. Interviewer bias was examined by using t-tests to compare mood scores across interviewers. The differences were not significant.

Survey design represented a potential bias in that taking the "before" interview might somehow subtly influence scores on the "after" interview. For instance, the first interview was surprising to people, but they were forewarned of the second. To test this possibility, I collected 56 after-only interviews at the Hampton Ponds area and compared these mood scores with the after scores of people who had completed both interviews at the area. The Mann-Whitney means test expanded for large sample sizes found no significant differences, indicating that taking the first test did not influence mood scores on the after interview.

Nonresponse constitutes the most serious source of bias. When a person refused to participate, the interviewer recorded the area, date, time, weather conditions, sex, and estimated age of the nonrespondent. Although subsequent chi-square tests revealed no differences between respondents and nonrespondents for these dimensions, it seems reasonable to assume that nonrespondents did differ significantly from respondents in some aspects of mood. Consequently, the ability to generalize from these data to the entire population of users at a specific area is impaired. On the other hand, the problems created by nonrespondents may be somewhat less important when comparisons of different activities are involved, because these comparisons include only people who were willing to participate.

Seven hundred and ninety-nine useable questionnaires were obtained: 120 from Skinner, 98 from Savoy, 59 from Hampton Ponds, 106 from Greylock, 98 from the Museum of Science, 97 from the New England Aquarium, 107 from the Martin Golf Course, and 114 from the Ponkapoag Golf Course. Only those respondents who completed both interviews were included in the analysis.

To compare the moods of visitors as they arrived at the area, a multivariate analysis of variance (MANOVA) was used. To identify the moods that differed significantly across the areas on the before interview, individual analyses of variance (ANOVA) were conducted after a correlation analysis had indicated that the moods could be treated independently. Finally, to assess which moods were most responsible for any overall mood differences between areas, a stepwise discriminant analysis treated moods as independent variables, using people's mood scores to predict the area they were in. When a mood was identified as significantly discriminating between the individual areas, it was subjected to multiple range tests to see if different levels of the mood were associated with the different recreation environments (i.e., forest, outdoor nonforest, and indoor).

To assess changes in mood, a change score was computed by subtracting scores on the after interview from scores on the before interview. To see if moods changed differently at different areas, a MANOVA was conducted on the change scores. Another stepwise discriminant analysis identified the moods that were most responsible for differences in mood score between areas, and the range tests were repeated. Individual ANOVAs conducted for each mood indicated if that mood had changed significantly during the recreation experience.

Finally, the results of the discriminant analyses were cross-checked by repeating MANOVAs on the subgroups of areas they identified, and the effects of the independent variables (socioeconomic and demographic variables, time, weather, etc.) were assessed by using MANOVA to compare mood and mood change scores across their different levels.

RESULTS

Moods of visitors arriving at the sites

The mean scores on each mood at every area are presented in Table 1 for both before and after interviews. Recall that the scores could range from 3 (very low) to 12 (very high). On this basis, the general pattern of mood scores across all the areas (and activities) appears similar—most people entered with low levels of negative moods and moderate levels of positive moods. Levels of concentration tended to be moderate, while fatigue levels were low. When the areas were compared, however, the MANOVA revealed that visitors did differ significantly ($p < 0.001$) in mood scores across areas. The ANOVAs conducted separately on each mood indicated that the area scores differed significantly in aggression, elation, vigor, social affection, and concentration ($p < 0.05$). These same moods also were significant ($p < 0.005$) in the discriminant analysis.

In this analysis, the moods most responsible for differences between areas were (in decreasing order of importance) social affection, vigor, elation, aggression, and concentration, with 19.5 percent of all individuals classified correctly by area. The discriminant analysis also identified subgroups of similar areas by plotting canonical variables evaluated at group means. This portion of the analysis identified the three major subgroups, separating visitors to state parks, golf courses, and museums correctly.

In sum, then, the first hypothesis—that people would enter all areas with low levels of negative moods and moderate levels of positive moods—appears generally true. However, the third hypothesis that there would be little difference in moods across the different areas—cannot be confirmed. While the general pattern of moods appears similar, it may be that anticipating a particular kind of recreation experience produces subtle shadings or gradations in people's feelings that are sufficient to differentiate between individual areas.

Table 1.—Mean mood scores before (B) and after (A) visits across areas

Mood[a]		State park				Golf course		Museum		All areas (N = 799)
		Skinner (N = 120)	Savoy (N = 98)	Hampton Ponds (N = 59)	Greylock (N = 106)	Martin (N = 107)	Ponkapoag (N = 114)	Science (N = 98)	Aquarium (N = 97)	
Negative:										
Aggression	B	4.2	3.8	3.9	3.9	4.3	4.3	3.5	3.5	3.9
	A	3.8	3.6	4.0	3.6	4.4	4.4	3.4	3.4	3.8
Anxiety	B	4.3	3.8	3.8	4.2	4.5	4.0	4.0	3.9	4.1
	A	3.8	3.6	3.7	3.8	3.8	3.9	3.7	3.4	3.7
Sadness	B	4.0	3.7	3.6	3.7	3.7	3.6	3.5	3.6	3.6
	A	3.8	3.6	3.8	3.6	4.4	4.4	3.4	3.4	3.8
Skepticism	B	4.8	4.6	4.8	4.5	4.7	4.8	4.3	4.3	4.6
	A	4.3	4.0	4.3	4.1	4.2	4.4	3.8	3.7	4.1
Egotism	B	4.3	4.4	3.9	4.2	4.7	4.6	4.0	4.1	4.3
	A	4.2	4.0	3.7	4.3	4.1	4.0	3.8	3.8	4.0
Positive:										
Surgency	B	8.0	8.3	7.9	8.0	7.8	8.3	7.6	7.9	8.0
	A	8.1	8.3	7.3	8.0	6.7	7.4	6.4	7.7	7.5
Elation	B	8.0	7.8	7.4	8.3	7.2	7.7	7.4	7.9	7.7
	A	8.7	7.6	6.9	8.4	6.2	6.4	7.1	8.1	7.5
Vigor	B	8.2	8.4	8.4	8.0	8.8	9.4	8.7	8.8	8.6
	A	7.7	7.6	7.2	7.7	6.5	7.3	6.3	7.9	7.3
Social affection	B	9.0	8.9	8.4	8.8	7.5	8.5	9.2	9.3	8.7
	A	9.0	8.9	8.3	8.5	6.7	7.5	8.3	8.9	8.2
Other:										
Concentration	B	7.1	7.2	7.5	7.0	8.0	7.8	8.0	8.0	7.6
	A	7.0	6.1	7.2	6.7	5.9	6.6	7.2	7.5	6.7
Fatigue	B	4.9	5.1	4.6	4.5	5.0	4.6	4.3	4.4	4.7
	A	4.7	4.9	4.8	4.2	6.6	5.7	6.0	4.7	5.2

[a]Moods are grouped conceptually into four groups: negative, positive, concentration, and fatigue (More and Payne 1978).

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8 p.
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Keywords: Recreation quality, recreation experience, outdoor recreation

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Mood changes during a recreation experience

ANOVAs conducted on individual mood scores indicated that most moods declined significantly ($p < 0.01$) during the course of the recreation experience. Sadness increased significantly ($p < 0.05$); aggression did not differ significantly, though the change was the predicted direction. This tends to confirm the second hypothesis—that the levels of both positive and negative moods decline significantly during on-site participation. However, the MANOVA results again indicated significant differences in mood changes between areas ($p < 0.001$). When broken down by the discriminant analysis, the moods most responsible for producing these differences ($p < 0.005$) were (in decreasing order of importance) vigor, concentration, sadness, fatigue, and elation (19.3 percent of cases correctly classified by area).

As before, three groups emerged when the canonical variables evaluated at group means were plotted. This time, however, one of the museums—the New England Aquarium—was included with the state parks, associated most closely with Mount Greylock. At Mount Greylock, people drive to the summit and spend about 45 minutes wandering about enjoying the views. Perhaps people experience aquaria in a similar fashion, treating the experience more as sightseeing than as an educational venture.

A MANOVA repeated on the groups of areas identified by the discriminant analysis found no significant differences within the group of state parks and the aquarium, indicating the moods changed in similar ways at these areas. However, when repeated for golf courses, significant differences ($p < 0.05$) were found. Subsequent ANOVAs indicated the two courses differed significantly on anxiety and concentration ($p < 0.05$).

While the discriminant analyses indicated that different moods and mood changes could discriminate among *individual* areas, the range tests were less successful in dividing individual areas into their appropriate recreation environment. Only in the case of aggression were the areas neatly classified into the three recreation environments; here, museum visitors scored lowest and golfers scored highest, with state park users falling in the middle.

Effects of independent variables on mood

Finally, the MANOVA comparisons of mood and mood change scores across different levels of the independent variables (age, sex, income, education, number in party, time, weather, etc.) indicated that none of these variables exerted a significant influence on mood. It may be these variables describe who participates in an activity rather than how they feel when they arrive at the site.

DISCUSSION

What is the emotional process that occurs during the recreation experience and how does it differ across activities and sites? For natural areas near cities, More and Payne (1978) suggested that the decision to participate in a recreational activity establishes a goal—arriving at the site and initiating participation. As people anticipate the experience, the amount of positive emotion builds until the goal is reached. Once on site, people consume the recreation experience until they reach a point where continued participation no longer seems desirable or an alternative activity becomes more pressing and they decide to leave. This consummation is accompanied by a slight but statistically significant decline in the level of positive emotion—when people leave, they are still in a "good" mood, but one that is down somewhat from the peak near the start of the experience. This process has been depicted graphically by More and Buhyoff (1979).

This study suggests that this emotional process is a general one, applicable to a variety of recreational activities. Two reasons support this: first, the general pattern of moods was the same across the activities—people both entered and left all the areas with moderate levels of positive moods and low levels of negative moods. This similarity is particularly striking since state park visitors, golfers, and museum visitors probably have vastly different motives for participating in their activities. Second, while the discriminant

analyses were significant, they were only marginally so; both analyses only managed to correctly categorize about 20 percent of the cases. Thus, while people's moods can be used to discriminate between areas, they do not provide a particularly good basis for doing so.

While this buildup and decline of positive moods may apply generally across all recreational activities, it still seems possible for specific moods to vary slightly across specific activities—the subtle shadings of mood referred to earlier. For example, while the general pattern of moods was similar across areas and the discriminant analyses were only marginally significant, the MANOVAs indicated that the areas differed significantly both in terms of entering moods and in the way moods changed during the course of the experience. The feelings most consistently responsible for producing these differences (i.e., those found to be significant in both discriminant analyses) were vigor, elation, and concentration. However, none of these could be clearly associated statistically with the three major types of recreation environments studied. In fact, aggression was the only mood that could be categorized as being highest for golfers and lowest for museum visitors, with state park users in the middle.

One potential reason for this inability to associate moods and environments is the sheer number of sites used. For example, had each environment—forest, outdoor nonforest, and indoor—been represented by only one site, the differences among them might have seemed more apparent. With eight areas, the chances of obtaining such a neat classification are greatly reduced; it may be that moods for a recreation environment are distributed about a mean, and that areas on an end of the distribution overlap areas of another environmental type. On this basis, there do seem to be some general *trends* in the data from this study, which, though not verifiable statistically, appear to make some sense intuitively. Relative to the other groups, state park visitors, for example, showed average levels of negative moods, and above average levels of surgency, elation, and social affection (Table 1). They were also concentrating less initially, while their experience left them feeling somewhat more vigorous and less fatigued than other groups. Golfers, on the other hand, tended to show the highest levels of negative feelings on both interviews. Initially, they had high levels of vigor and concentration coupled with below average levels of social affection, perhaps attributable to the competitive nature of the game. However, their recreational experiences left them, as a group, with below average scores on surgency and concentration, and well below average scores on elation and social affection. Fatigue levels increased substantially.

The museum visitors consistently showed the lowest levels of negative moods on both interviews. They began their experience with above average levels of vigor, concentration, and social affection, coupled with lower than average levels of surgency and fatigue. When leaving, they still showed above average levels of concentration and social affection.

While many of these differences seem intuitively appealing, recall that, as mentioned earlier, they do *not* represent statistically significant differences between recreation environments. This may be due, in part, to the fact that the MACL provides only a crude, although comprehensive, index of people's feelings (Nowles 1965); the differences might be more apparent with a more finely calibrated instrument or with different indicator variables. Future research using different sites and activities and alternative instrumentation will have to clarify the reasons for and extent of these differences before definitive statement can be made about one type of environment producing a specific feeling.

Thus far, I've been discussing what I believe is a general process that applies to most people most of the time. Yet it is important to recognize that in addition to differences between sites, there can be a vast array of individual differences in recreation experiences and the moods they foster. All of us can recall individual experiences that stand out either positively or negatively; over the population of users of a given site or facility, some will be excited by it, others turned off. Some people are simply more "into" an activity than others.

Understanding these differences and how they are incorporated into the general recre-

ational process provides a basis for managing recreation quality (More and Buhyoff 1979). First, one must be conscious of the buildup and decline of emotion that occurs generally during the recreation experience—on an emotional level we may be dealing with entirely different user populations at the beginning and end of an experience. Because of this, the timing and location of a variety of management activities becomes important. For example, people may be more responsive to requests for information or donations earlier in their experience than they are later.

Similarly, attempts to communicate rules should be more effective early in the experience, and care should be given to the location of interpretive and information facilities to ensure that people encounter them near the start of their experience. Programed events such as interpretive walks or instruction might also best be scheduled at times when most visitors are fresh and receptive to information. Conversely, since people at the end of an experience tend to be in not quite such a good humor, they may be somewhat more prone to complain at this time. Consequently, managers would probably do well to avoid controversial features, requests, or presentations that people might encounter near the end of a visit.

From the standpoint of individual differences, More and Buhyoff (1979), following Lewin (1951), suggested that a recreation experience should be treated as a series of goals, and the amount of emotion people experience is related to how attractive they find these goals. Thus, from a management standpoint, we need to identify and manipulate those attributes of the goals that people find attractive (cf. Peterson 1974). In this way it may be possible to have a positive impact on the emotional aspects of people's recreation experiences.

CONCLUSION

Are there differences in the emotional effects of recreation environments? On the basis of the data in this study, I cannot conclude that there are with any degree of confidence. Certainly, there are differences in moods and mood changes between individual areas, and there appear to be some interesting—though not statistically significant—trends in the data. However, until future research examines these trends in greater detail using different sites, activities, and other, more precise indicators, it is premature to conclude that there are major emotional differences among forest, outdoor nonforest and indoor recreation environments. Sweeping statements asserting unique psychological benefits for outdoor recreation are, at best, oversimplifications.

In sum, two of the major hypotheses of this study were confirmed: people did arrive at all areas with low levels of negative moods and moderate levels of positive moods, and the levels of most moods declined during participation. On the basis of these results, I believe there is a general process involving a buildup of positive emotions during anticipation followed by a decline during consummation. However, individual moods, while generally conforming to this process, may vary slightly between activities, producing subtle differences in people's experiences. Research is needed to examine these differences in greater detail, especially in relation to specific attributes of a site that can be regulated by managers. When we understand more about the relationship between people's moods and these attributes, we will be better able to attain one of the most important goals of recreation management and research—providing high-quality recreation experiences for the general public.

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by Neil Lamson

Site Index Prediction Tables for Oak in NORTHWESTERN WEST VIRGINIA

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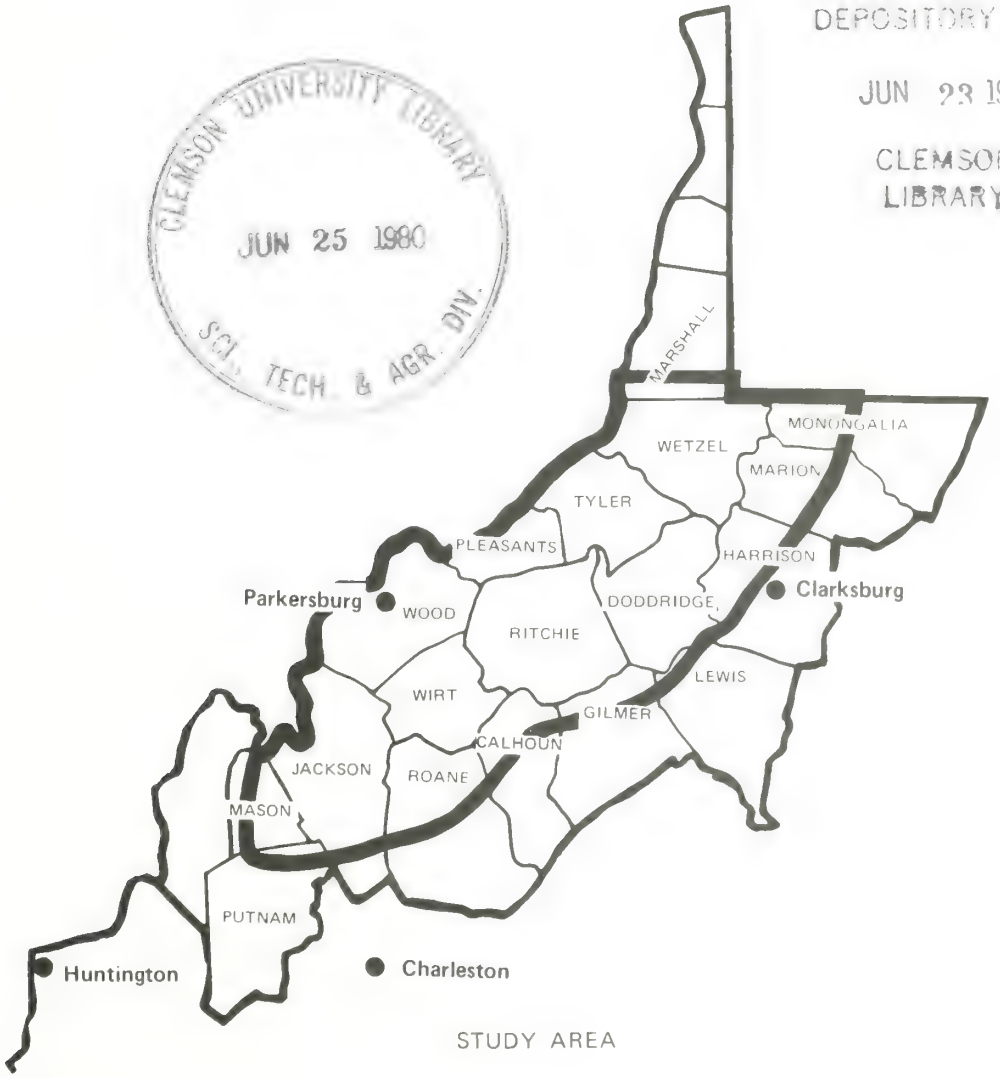

FOREST SERVICE RESEARCH PAPER NE-462
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FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Abstract

Prediction tables for even-aged stands of white, chestnut, northern red, scarlet, and black oaks can be used to estimate the site index of forest land in 13 counties of northwestern West Virginia. The half-width of the 95 percent confidence interval of the predicted site index is included; it can be used to determine the number of sample trees necessary to attain given levels of precision, or to determine the precision of a site index prediction for different numbers of sample trees.

BACKGROUND

SITE INDEX, the height of dominant and codominant trees at age 50, is the most commonly used indicator of forest site productivity in eastern hardwoods. Height growth curves, commonly referred to as site index curves, show the height growth patterns of trees on various sites. These curves are usually developed by taking height measurements of trees over a range of ages or by stem analysis techniques (Curtis et al. 1974).

Site index prediction tables presented in this paper were developed by first determining the age of sample trees at 4-foot intervals along the stem. These data were used to determine the height of the trees at various ages. Then, by methods similar to Curtis's (1964), linear regressions were calculated for ages 10 to 80 by 5-year intervals. Site index is better predicted from known tree heights and ages with this type of site-index prediction table than by height/growth curves because the estimated variable, site index, is the dependent variable in the calculations (Curtis et al. 1974).

Figure 1.—The region studied includes about 3 million acres of forest land in northwestern West Virginia. Region boundaries are delineated by uniform climate, topographic configuration, and the geologic formation from which the dominant soils have formed.

TREE SELECTION AND DATA COLLECTION

Study trees were selected in Wetzel, Monongalia, Marion, Doddridge, Harrison, Tyler, Pleasants, Ritchie, Wood, Wirt, Calhoun, Roane, and Jackson counties in northwestern West Virginia (Fig. 1). Eighty-one trees were measured on 27 plots that were established in even-aged stands 50 to 105 years old. Stands were selected over the range of site qualities in the area (Table 1). Only straight, codominant or dominant trees with no outward signs of suppression or fire, insect, or disease damage were selected. Age at 4.5 feet was determined from increment cores. Study tree ages ranged from 53 to 107 years.

Table 1.—Number of plots sampled and trees sectioned[a] by site index class

Species	Site index class				Total number of trees sectioned
	46-55	56-65	66-75	76-85	
Chestnut oak	2 (6)	1 (2)	1 (2)	—	10
White oak	2 (4)	3 (8)	4 (11)	1 (3)	26
Scarlet oak	—	2 (5)	2 (6)	—	11
Red oak	—	1 (3)	5 (11)	2 (4)	18
Black oak	1 (3)	—	4 (11)	1 (2)	16
Total number of trees sectioned	(13)	(18)	(41)	(9)	81

[a]Numbers in parentheses are the number of trees sectioned; 2 (6) refers to 6 trees on 2 plots.

If the tree's age was within 10 years of the estimated stand age, it was felled and sectioned at 4-foot intervals. Age was determined at each sectioning point.

DATA ANALYSIS

The height above ground of each sampling point was corrected for inherent bias (McQuilkin 1974, Carmean 1971). Although the ring counts gave the age at a specific height, the total height of the tree at that age would be slightly greater because the cut probably was made somewhere in the middle of the height growth for that year. So half the average annual height growth of the tree at that age was added to the height of the sectioning point to obtain total tree height. Total tree height over age was plotted for each sample tree. Trees that showed signs of early suppression or top breakage (irregular height growth) were discarded. The total height at 5-year intervals was determined from the height-over-age graphs. These data were used in all subsequent calculations.

The data were stratified by species. A linear regression, SI = a + b (ht), was calculated for each 5-year age class and each species. Comparisons of the curves showed that chestnut (*Quercus prinus* L.) and white oaks (*Q. alba* L.) were not significantly different, nor were northern red (*Q. rubra* L.), black, (*Q. velutina* Lam.), and scarlet oaks (*Q. coccinea* Muenchh.). Thus, the data were combined into two species groups—red oaks and white oaks—and the 5-year regression equations were recalculated. These equations were used to construct the site index prediction tables (Tables 2 and 3).

The half-width of the 95 percent confidence interval of each site index equation was calculated with the formula

$$HW = \pm t\,(s)$$

in which t is the value of the t distribution at the .975 probability level with degrees of freedom (number of trees minus 2) and s is the standard error of the stand site index.

The standard error of the stand site index was calculated as the square root of the variance, V, of the stand site index which was calculated with formula 6 from McQuilkin and Rogers (1978).

$$V = S_{SI \cdot H^2} \left[\frac{1}{k} + \frac{1}{n} + \frac{(\bar{h}_A - \bar{H}_A)^2}{\sum_{i=1}^{n} (H_{Ai} - \bar{H}_A)^2} \right] + b^2 \frac{V(h_A)}{k} .$$

where

$S_{SI \cdot H^2}$ = mean square error term of the regression

k = number of future sample trees

Table 2.—Site index estimates for northern red, scarlet, and black oaks

Stand age (years)	Height (feet)																
	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
20	51	56	60	64	68	72	76	81	85								
25		50	54	58	62	66	70	74	78	82							
30			48	52	56	61	65	69	73	77	82						
35				45	50	54	59	63	67	72	76	81					
40						48	52	57	62	66	71	75	80				
45							46	51	55	60	65	70	75	80			
50								45	50	55	60	65	70	75	80		
55									46	51	55	60	65	70	75	80	
60										47	52	56	61	66	71	76	81
65											48	53	58	63	68	73	78
70												50	55	60	65	69	74

Lamson, Neil
1980. **Site index prediction tables for oak in northwestern West Virginia.** Northeast. For. Exp. Stn., Broomall, Pa.
5 p., illus. (USDA For. Serv. Res. Pap. NE-462)

Prediction tables for even-aged stands of white, chestnut, northern red, scarlet, and black oaks can be used to estimate the site index of forest land in 13 counties of northwestern West Virginia. The half width of the 95 percent confidence interval of the predicted site index is included; it can be used to determine the number of sample trees necessary to attain given levels of precision, or to determine the precision of a site index prediction for a known number of sample trees.

541 176.1 561.1

Keywords: *Quercus alba, Quercus prinus, Quercus rubra, Quercus coccinea, Quercus velutina,* confidence intervals.

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Table 3.—Site index estimates for white and chestnut oaks

Stand age (years)	Height (feet)															
	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
20	44	51	58	65	72	79	86									
25	37	43	50	57	63	70	76	83								
30			43	50	56	62	68	75	81	87						
35				42	48	54	61	67	73	79	85					
40					42	48	54	60	66	72	78	84	90			
45						43	49	54	60	65	71	77	82			
50						40	45	50	55	60	65	70	75	80	85	
55							42	47	51	56	60	65	69	74	79	83
60							40	44	48	52	57	61	65	69	73	77
65							39	43	46	50	54	58	61	65	69	73
70								41	45	48	52	55	59	62	66	69

n = number of sample trees used to calculate the regression

b = regression coefficient

$V(h_A)$ = within-plot variance of the future sample tree heights

h_A = mean height of k future sample trees at age A

$H_{A\,i}$ = height at age A of the i^{th} tree (i = 1 to n)

$\overline{H}_A$ = mean height of age A of all n trees used in the regressions.

The half-width of the 95 percent confidence intervals for stands from 10 to 80 years old when the number of sample trees ranges from 5 to 25 are presented in Table 4.

The within-plot variance of the future sample tree heights was assumed to be the same as the within-plot variance of the sample tree heights used to calculate the regression. In practice, the variance of the future sample tree heights will be less than the value used in these calculations because a single even-aged stand will have less height variation than trees selected over a wide range of site qualities. Therefore, the half-widths of the 95 percent confidence intervals presented in Table 4 are wider than those that normally would be encountered when using these tables to estimate the site index of an individual stand.

Table 4.—Half-width of the 95 percent confidence interval of the predicted site index when the number of sample trees ranges from 5 to 25 trees

Stand age	Half-width of confidence interval (± feet) when number of sample trees is				
	5	10	15	20	25
	NORTHERN RED, SCARLET, AND BLACK OAKS				
20	6.2	4.8	4.2	3.8	3.6
25	6.1	4.7	4.1	3.7	3.5
30	5.6	4.4	3.9	3.6	3.4
35	4.9	4.0	3.6	3.3	3.1
40	4.0	3.4	3.1	2.9	2.7
45	3.9	3.5	3.2	3.0	2.9
50	3.3	3.1	2.9	2.7	2.6
55	3.2	2.9	2.7	2.5	2.4
60	3.6	2.6	2.3	2.0	1.9
65	4.1	3.1	2.7	2.5	2.4
70	5.1	4.0	3.5	3.3	3.1
	WHITE AND CHESTNUT OAKS				
20	7.6	5.9	5.1	4.7	4.4
25	6.8	5.2	4.6	4.2	3.9
30	5.9	4.7	4.1	3.8	3.5
35	4.9	4.0	3.6	3.4	3.2
40	4.3	3.7	3.4	3.1	3.0
45	3.9	3.5	3.3	3.1	2.9
50	3.4	3.2	3.0	2.8	2.7
55	3.8	2.7	2.2	2.0	1.8
60	3.7	2.7	2.3	2.0	1.9
65	3.9	2.9	2.5	2.3	2.2
70	4.8	3.7	3.2	3.0	2.8

HOW TO USE THE SITE INDEX PREDICTION TABLES

1. Delineate the stand to obtain relatively uniform site and tree age.

2. Determine the stand age by boring several trees and use Table 5 to determine the number of sample trees needed. For example, 10 sample trees would be needed to predict the site index with a 95 percent confidence interval of 8 feet in a 35-year-old red oak stand. Trees used for age determination that are within 10 years of the average stand age can be used for site index determination in step 4; therefore straight, undamaged, dominant or codominant trees should be selected.

3. Randomly select sample trees. Use only straight, undamaged, dominant or codominant trees with no signs of past height-growth depression. Forks and crooks are good indications that the top may have been broken, reducing total height of the tree.

4. For each sample tree:
   a. Determine the age at breast height and add 2 years to get total age. If the total age of the sample tree differs by 10 years from stand age, do not use the tree, but find a sample tree that is within 10 years of the stand age. To reduce the number of trees bored, trees bored in step 2 that are within the 10-year limit can be used.
   b. Measure the total height. On larger trees, at least two measurements should be averaged to estimate total height because it is difficult to see the tops of large trees.
   c. Use Table 2 or 3 to determine the estimated site index. For example, the estimated site index for a 35-year-old, 40-foot-tall red oak tree is 59 feet (Table 2).

5. Average the estimated site indexes from the sample trees to determine the average site index of the stand.

DISCUSSION

To use these site index prediction tables, it is essential that at least the recommended number of sample trees be measured. For example, from Table 4 for a 20-year-old white oak stand, 15 sample trees are needed to estimate the site index so that the half-width of the confidence interval is 5.1 feet. In other words, if the average site index of the sample trees was 67 feet, one would be 95 percent confident that the true site index is between 61.9 and 72.1 feet. If, for example, only 5 trees had been sampled, the half-width of the confidence interval would have been ±7.6 feet.

These site index tables were developed from data on trees in even-aged stands, and should be used only in even-aged stands.

Height growth curves constructed from site index prediction tables cannot be compared to height growth curves constructed from stem analysis data (Carmean 1971) or from plot observations over a range of stand ages (Schnur 1937). However, tree age and height data can be used to predict site index from both site index prediction tables and height growth curves. In this sense, site index predictions are comparable between Tables 2 and 3, Carmean's (1971) height growth curves, and Schnur's (1937) height growth curves. Comparisons showed that for trees 50 to 70 years old, these site index prediction tables gave estimates of site index up to 5 feet higher than estimates from either Carmean's or Schnur's height growth curves. For ages 30 to 50 years, these site index estimation tables gave estimates up to 3 feet lower than did Carmean's or Schnur's height growth curves. Since these differences are not large enough to change the 10-foot site index class of a plot, Schnur's (1937) yield tables can be used with these site index estimation tables.

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GUM SPOTS caused by cambium miners in BLACK CHERRY in West Virginia

AUG 21 1980

by Charles O. Rexrode
and John E. Baumgras

FOREST SERVICE RESEARCH PAPER NE-463
1980

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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JOHN E. BAUMGRAS attended Michigan State University, where he received a B.S. degree in forestry in 1965 and an M.S. degree in forest management in 1967. After working as a forester on the Monongahela National Forest, he joined the Northeastern Forest Experiment Station, Forestry Sciences Laboratory at Princeton, W. Va. He is currently engaged in research in timber harvesting economics, including commercial thinning in eastern hardwoods.

MANUSCRIPT RECEIVED FOR PUBLICATION 11 APRIL 1980

Abstract

Six types of gum spots in black cherry, *Prunus serotina* Ehrh. were associated with parenchyma flecks caused by the cambium miner *Phytobia pruni* (Gross). The number of parenchyma flecks and associated gum spots increased with the height of the tree. Four percent of the flecks produced gum spots in the first 18 to 20 feet of the trees; 8 percent of the flecks produced gum between 20 and 60 feet. Most parenchyma flecks and associated gum spots occurred during the first 10 to 15 years of cambial growth.

INTRODUCTION

BLACK CHERRY, *Prunus serotina* Ehrh., is a valuable component of the forests of West Virginia and particularly the Monongahela National Forest. Although Pennsylvania leads in the production of black cherry, West Virginia will soon be a major source of supply for black cherry veneer and sawtimber. For example, in 1972, the Monongahela National Forest had 500 million board feet of black cherry, more than any other single tree species. This is a 100 percent increase since 1962; and from the average tree diameter and the current rate of growth, the total volume of black cherry is expected to double again by 1990.

Throughout the commercial range of black cherry, gum spots are a serious problem because they reduce timber quality. Logs rejected for veneer stock because of certain gum spots may lose 50 percent or more of their value. Factory grade 1 and 2 sawlogs may be reduced one grade when gum spots affect a large area of the log quality zone (Rast et al. 1973).

The severity of the problem varies greatly, both regionally and locally. For example, timber operators in Pennsylvania say that from 10 to 90 percent of logs, depending on locale, will be rejected for veneer because of gum spots. Gum spots are so bad in black cherry in some counties and areas of Pennsylvania that operators will not bid on timber sales.

Black cherry in West Virginia has the reputation of being "gummy"; yet cherry veneer logs are being marketed within the state. One problem confronting timber managers is the lack of information on the occurrence, distribution, and causes of gum spots in black cherry. They need to know the severity of the problem, as black cherry has become an important timber species in the state.

Gum defects in black cherry wood are often associated with parenchyma flecks, which are generally believed to be caused by larval activities of the agromyzid cambium miner, *Phytobia pruni* (Gross). Parenchyma flecks are larval galleries that have been buried by cambium growth, resulting in a discolored area consisting of damaged parenchyma cells and insect feces (Kulman 1964). This cell damage often produces traumatic lysigenous gum canals, or the gum spots found with parenchyma flecks (Panshin and de Zeeuw 1964). Parenchyma flecks alone are seldom a serious defect.

Hough (1963) stated that most of the gum defects in black cherry in Pennsylvania were caused by the cambium miner *P. pruni*. However, in two areas of West Virginia, Kulman (1964) showed that only 11 percent of the parenchyma flecks caused by the cambium miner *P. pruni* produced gum defects and they were of minor importance compared to other causes of gum spots.

The objectives of this study were to determine the frequency and distribution of gum spots caused by the cambium miner *P. pruni* in black cherry trees growing under a variety of conditions.

METHODS AND MATERIALS

This study was conducted on the Monongahela National Forest in Randolph and Pocahontas counties of West Virginia during 1978-79. One hundred and seventeen trees, 5 to 16 inches in dbh, from seven areas over a range of 30 miles were studied. A cross section, 2 inches thick, was taken from each of 63 trees at 1-foot, 4.5-foot, and at each subsequent 5-foot interval to a 5-inch top. For 54 trees, a cross section, 2 inches thick, was taken from each tree at 1-foot and at subsequent 8- to 16-foot log lengths to a 6-inch top.

All trees sampled were growing under similar stand conditions—high density of stocking with slow tree growth. The rate of diameter growth was about 1/20 inch per year during the last 20 years and the bole-to-crown ratio was about 80:20. The trees were sampled from areas where the density of stocking of all tree species ranged from 463 to 837 trees per acre with basal areas of 132 to 180 ft^2 per acre. The basal area in black cherry trees ranged from 14 to 68 percent. The study areas were between 3,000 and 3,800 feet elevation with 0 to 40 percent south-south-east slopes and with site indexes[1] of 60 to 90.

One surface on each 2-inch-thick disc was divided into four equal quadrants and one randomly selected quadrant from each disc was sanded to obtain a smooth surface. Each selected quadrant was treated with glycerin and examined under a stereozoom binocular microscope equipped with a rotatable arm. All defects were recorded by type and year of occurrence and the total number of defects on each quarter section was multiplied by 4 to estimate the number of defects per disc.

The diameter at 4.5 feet, crown class, and total height of each tree were recorded. Data were also collected for the following site and stand characteristics: elevation, slope, aspect, site index, basal area per acre, and number of trees per acre.

[1] Site index based on average total height of dominant and codominant black cherry trees at 50 years of age.

RESULTS

Parenchyma flecks were present in all trees sampled and were similar to those described by Hough (1963) and Kulman (1964). The flecks were crescent-shaped, averaged about 3 mm in length and 0.5 mm in width, and extended across several rays in the springwood (Fig. 1). A yellow to brown amorphorus material was present in most flecks but relatively few flecks contained gum.

Six types of gum defects were associated with parenchyma flecks on transverse sections of the trees. Type I was a normal parenchyma fleck with one or two small gum spots that occurred between the rays (Fig. 2). They were usually at the ends of the fleck on the bark side. Type II was a normal parenchyma fleck with gum spots between the rays along the entire edge of the fleck on the bark side (Fig. 3). Type III was an accumulation of gum that filled the entire parenchyma fleck (Fig. 4). Type IV was an accumulation of gum that filled the entire fleck with interray gum spots on one or both ends of the fleck (Fig. 5). Type V was a normal parenchyma fleck with a single continuous line of interray spots on either end of the fleck (Fig. 6). Sometimes the gum spots would extend 20 mm from the fleck. Type VI was an accumulation of gum that filled the entire fleck with gum and had interray gum spots on all sides of the fleck appearing as one large gum spot, 5 mm wide and 8 mm long (Fig. 7).

The distribution of parenchyma flecks and types of gum spots associated with flecks in the trees are shown in Tables 1 and 2. The number of flecks with gum defects was small but was correlated with the increase in the total number of flecks. The average number of parenchyma flecks per sample, with and without gum, increased with the height of the sample in the tree. The average number of parenchyma flecks and flecks containing gum was substantially less in the first 18 to 20 feet of the trees. Only 4 percent of the parenchyma flecks in the first 18 to 20

Text continued on page 6

Figure 1.—Normal parenchyma flecks in black cherry caused by *Phytobia pruni* (Gross) (6X).

Figure 2.—Normal parenchyma fleck with one or two interray gum spots on the outside edge of the fleck (6X).

Figure 3.—Normal parenchyma fleck with interray gum spots along the entire outside edge of the fleck (6X).

Figure 4.—Parenchyma fleck filled with gum (6X).

Figure 5.—Parenchyma fleck filled with gum and interray gum spots on the end of the fleck (6X).

Figure 6.—Normal parenchyma fleck with a single continuous line of interray gum spots on the end o fleck (6X).

Figure 7.—Parenchyma fleck filled with gum and interray gum spots on all sides of the fleck (6X).

Table 1.—Distribution (average number and range) of parenchyma flecks and associated gum defects in 63 black cherry poletimber trees from five areas

Height of sample (feet)	Normal parenchyma flecks		Parenchyma flecks with gum		Type of gum defect[a]									
					I		II		III & IV		V		VI	
1	35	0-128	1.2	0-48	1.5	0-48	.5	0-20	—	—	1.7	0-40	—	—
4.5	42	0-216	.7	0-12	.7	0-12	—	—	—	—	—	—	—	—
9.5	61	0-164	1.4	0-36	2.4	0-36	.5	0-12	—	—	—	—	—	—
14.5	93	0-432	1.7	0-60	2.6	0-32	.8	0-32	1.7	0-60	—	—	—	—
19.5	137	36-420	1.6	0-60	1.7	0-60	1.6	0-16	—	—	—	—	—	—
24.5	164	8-384	3.5	0-72	4.3	0-64	5.2	0-72	—	—	1.1	0-48	—	—
29.5	183	40-580	2.8	0-92	4.5	0-40	4.7	0-92	.7	0-20[b]	.2	0-12	—	—
34.5	162	20-520	2.9	0-104	6.5	0-80	4.4	0-104	.2	0-8	—	—	0.4	0-16
39.5	142	56-624	3.0	0-52	8.2	0-52	3.3	0-44	.3	0-20	—	—	.2	0-8
44.5	207	56-552	16.2	0-128	24.2	0-128	8.7	0-88	—	—	—	—	—	—
49.5	230	52-1068	11.2	0-48	15.6	0-28	6.7	0-48	—	—	—	—	—	—
54.5	184	40-296	10.2	0-80	19.5	0-80	7.8	0-52	—	—	3.0	0-52	—	—
59.5	264	84-420	11.0	0-88	22.7	0-88	2.7	0-48	—	—	7.5	0-88	—	—
64.5	214	52-480	13.5	0-80	12.8	0-80	.4	0-4	—	—	—	—	—	—

[a]Types of defects:
I. One or two gum spots on outside edge of fleck.
II. A row of gum spots on outside edge of fleck.
III. Fleck filled with gum.
IV. Fleck filled with gum and gum spots at end.
V. A row of gum spots on the end of fleck.
VI. Fleck filled with gum and gum spots on all sides of fleck.

[b]Type IV defects.

Table 2.—Distribution (average number and range) of parenchyma flecks and associated gum defects in 54 black cherry sawtimber trees from two areas

Height of sample (feet)	Normal parenchyma fleck		Parenchyma flecks with gum		Type of gum defect[a]					
					I		II		III	
1	25	0-160	.4	0-8	.1	0-2	.1	0-2	.9	0-8
12	81	12-420	2.1	0-14	1.9	0-14	2.2	0-13	2.3	0-9
22 (18-26)[b]	179	0-680	5.0	0-64	7.5	0-34	7.0	0-64	3.0	0-32
30 (24-42)	231	20-576	4.1	0-92	8.3	0-92	6.4	0-52	1.3	0-4
43 (30-52)	413	92-1112	8.4	0-96	14.5	0-52	13.3	0-92	1.8	0-32
52 (44-60)	387	64-1004	12.9	0-64	22.7	0-31	11.5	0-64	4.4	0-28

Height of sample (feet)	IV		V	
1	—	—	—	—
12	—	—	—	—
22 (18-26)[b]	1.8	0-24		
30 (24-42)	.3	0-4		
43 (30-52)	4.4	0-96		
52 (44-60)	—	—		

[a] Types of defects: See Table 1.
[b] Average and range.

feet of the trees produced gum, but 8 percent of the flecks between 20 and 60 feet produced gum.

Although parenchyma flecks and related gum spots occurred yearly in every tree, the range in age of flecks and gum spots remained about the same regardless of the age and sample height of the cross sections (Table 3). In black cherry poletimber, most of the parenchyma flecks and related gum spots were produced during the first 10 to 15 years and continued until age 20 to 25, regardless of sample age or level of tree. Most of the flecks and related gum spots in black cherry sawtimber occurred also during the first 10 to 15 years and continued until age 30 to 42.

In poletimber trees, parenchyma flecks stop forming at a given sample height once the tree top reaches 30 to 40 feet above the sample (Fig. 8). This was determined by comparing the height of the samples with the estimated tree height at the date of the last parenchyma fleck at each sample height. Tree heights were estimated from sample height and ages. This comparison was developed from the composite poletimber data in Table 3. Sawtimber trees, which were about the same age as the poletimber trees but grew faster because of their well-developed dominant crowns, showed parenchyma flecks extending over a much wider height range within a growth ring. For example, flecks occurred in the 1964 ring from the 1-foot to the 52-foot level.

No relationships were found between the occurrence and frequency of parenchyma flecks or gum spots and the following tree and area characteristics: tree height, elevation, slope, aspect, site index, basal area, and tree density.

DISCUSSIONS AND CONCLUSIONS

Gum defects in black cherry were found to be directly associated with parenchyma flecks caused by the cambium miner, *Phytobia pruni*. A variety of gum defects were found, ranging from one or two small gum spots at the end of a parenchyma fleck to parenchyma flecks filled by gum and with

Table 3.—Age of sample section and range in age of cambium that produced rings in which flecks occurred—average of 63 trees from five areas for poletimber; average of 53 trees from two areas for sawtimber

Height of sample (ft above ground)	Average sample age	Any range of cambium producing flecks	Years flecks occurred
	BLACK CHERRY POLETIMBER		
1	56	2-22	1922-1944
4.5	52	2-23	1924-1947
9.5	48	2-24	1928-1952
14.5	46	2-26	1930-1956
19.5	44	3-24	1934-1958
24.5	42	3-28	1935-1963
29.5	40	2-28	1938-1966
34.5	37	3-26	1941-1967
39.5	35	2-23	1944-1967
44.5	32	3-28	1946-1974
49.5	29	3-26	1948-1974
54.5	27	3-28	1950-1978
59.5	24	3-25	1953-1978
64.5	21	3-24	1954-1978
	BLACK CHERRY SAWTIMBER		
1	60	2-44	1920-1964
12	52	2-35	1929-1964
24 (18-26)[a]	46	3-38	1932-1970
30 (24-42)	42	3-38	1936-1974
43 (30-52)	37	3-36	1942-1978
52 (44-60)	34	3-33	1945-1978

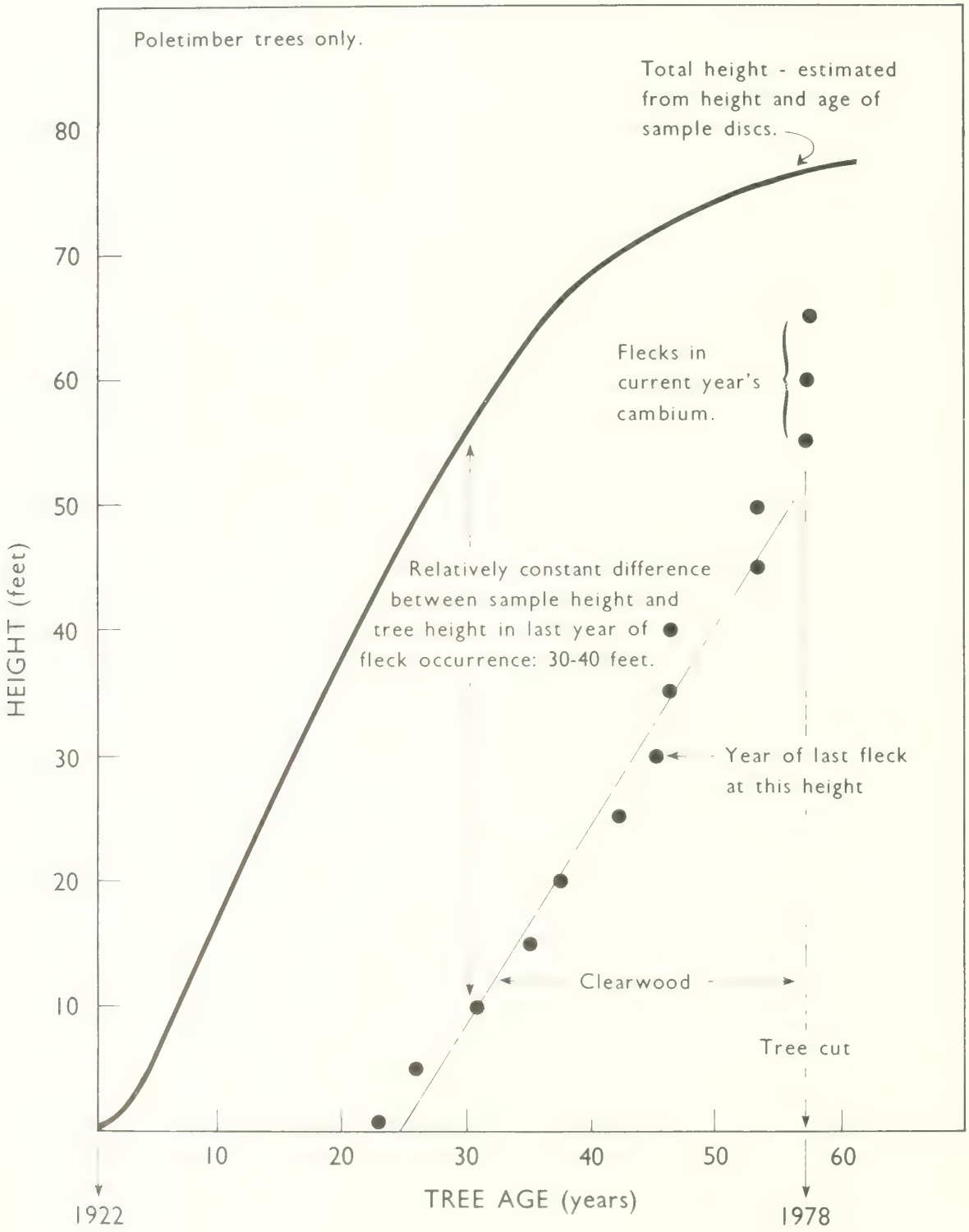
[a] Average and range.

gum spots on all sides of the fleck. The most common were a normal parenchyma fleck with one or two gum spots and a normal parenchyma fleck with a row of gum spots (Tables 1 and 2). All types of gum defects were interray and occurred within the growth rings in the springwood. The number of parenchyma flecks and associated gum defects increases with the height of the tree, with fewer flecks and gum defects in the first 18 to 20 feet than higher in the tree. The range in age of the cambium that produced the rings in which parenchyma flecks occurred remained about the same with the height of the tree. However, the range was greater for the more vigorous sawtimber trees than for poletimber trees.

In the trees studied, gum defects directly associated with parenchyma flecks were of minor importance compared to the total number of gum spots of other causes. There were many parenchyma flecks in each tree, but few produced gum that constituted a defect and the ones that did occurred near the center of the tree, the core that is discarded during the manufacture of veneer or the center of a sawlog that normally produces lower grade lumber.

According to Grossenbacker (1915), adults of the cambium miner insert their eggs in the lenticels of small twigs in May and June. The larvae hatch in about 3 days and bore downward through the cambial area, constructing a channel several times as wide as

Figure 8.—Comparison of sample height to total tree height in year last flecks occurred at a given sample height.



their bodies. The cambium miner overwinters as a partly grown larva in the tree and resumes feeding early in the spring. When approaching ground level, the larvae frequently move up and down within a few feet of the base of the tree before boring out through the bark and pupating in the soil. Our data did not substantiate the up and down movement of larvae near the base of the tree because the average number of flecks increased with the height of sample (Tables 1 and 2). Earlier workers also stated or implied that larvae bore all the way from the branches down to the base of the tree. However, we found an absence of flecks at the base of trees in annual rings that had flecks at higher levels; compare the age of the cross section and the range in age of the cambium producing the fleck (Table 3). Grossenbacker also stated that the cambium miner overwinters as a partly grown larva in the tree and resumes feeding early in the spring. This would mean that the cambium miner spent one year in the tree as a larva. If this were the case, one would expect to find larval mines in the summerwood as well as the springwood. In this study, all larval mines were in the springwood, indicating that the insect attacked in early spring and emerged before or during summer.

Results of this study indicate that gum defects caused by the cambium miner are not a serious problem in black cherry in West Virginia. Our results were similar to those reported by Kulman (1964) for black cherry near Parsons, West Virginia. Kulman also reported that gum spots produced by cambium miners were of minor importance compared to other causes of gum spots. However, gum spots per se are still a serious problem. Studies are now being made on the occurrence and frequency of gum spots in black cherry by agents other than the cambium miner.

If black cherry trees are growing vigorously and have large crowns, gum defects caused by the cambium miner may be a more serious problem, as suggested by Hough (1963). Future studies should bear this out. Plans are also being made to conduct similar studies on black cherry growing in a variety of timber stand conditions where records of microsite environmental influences have been maintained.

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by David A. Gansner
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COOPERATIVE FORESTRY ASSISTANCE in the Northeast

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Abstract

Summarizes results of a recent inventory of service forester activities in 20 Northeastern States. Each year some 500 local state foresters give one-half million hours of technical assistance and advice about the management of forest resources to nearly 50,000 woodland owners. Yearly on-the-ground help with activities ranging from timber sales to shade tree protection involves more than 2 million acres of nonindustrial private forest.

STATE SERVICE FORESTERS are the "main men and women" of the overall forestry assistance effort in the Northeast. Each year some 500 of these local public foresters give one-half million hours of technical assistance and advice about the management of forest resources to nearly 50,000 woodland owners. Yearly on-the-ground help with activities ranging from timber sales to shade tree protection involves more than 2 million acres of nonindustrial private forest. The cost to Federal and state taxpayers is about $9 million per year.

These findings are among the results of a recent inventory of service forester activities in 20 states (Connecticut, Delaware, Illinois, Indiana, Iowa, Maine, Maryland, Massachusetts, Michigan, Minnesota, Missouri, New Hampshire, New Jersey, New York, Ohio, Pennsylvania, Rhode Island, Vermont, West Virginia and Wisconsin). Data for the analysis were derived from a sample of more than 2,500 case records drawn from service forester files.

Results have been summarized to give a comprehensive, up-to-date look at service forester activities in the region. They provide information needed for judging the current worth and effectiveness of the Cooperative Forestry Assistance program and for identifying ways to improve its operation.

The 506,000 hours spent in service forestry each year averages about 10 hours per case. But, this average is not the best measure of the typical situation. Two-thirds of the cases require less than 10 hours while a few require 50 hours or more (Fig. 1). For skewed data distributions like this, the median (the value that divides the range of values into two equal parts) better describes what is "typical." The median number of service forester hours spent per case is 7, as indicated at the 50 percent level in Figure 1. Clients own woodlands ranging in size from one to several thousand acres. The median amount of woodland owned is about 50 acres (Fig. 2).

Figure 1.—Time spent on cases.

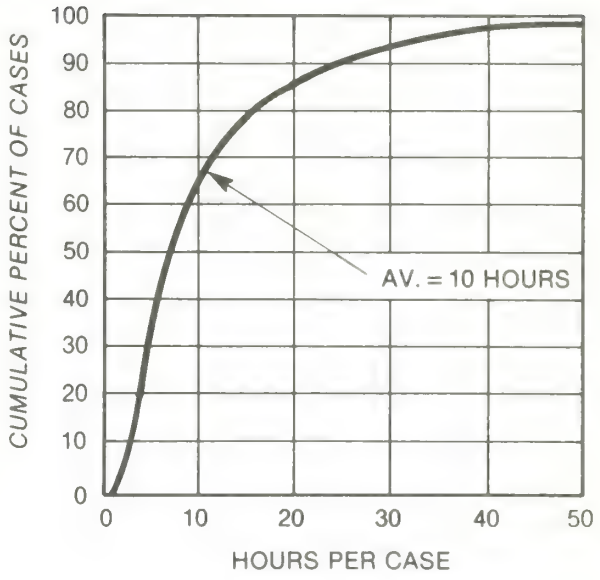
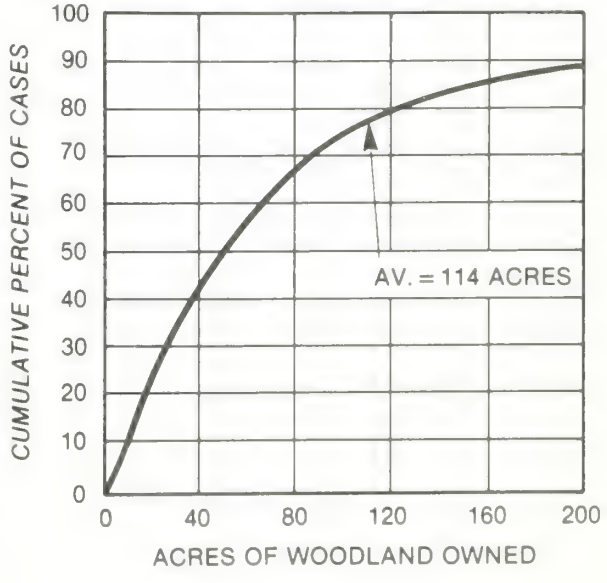


Figure 2.—Woodland owned by recipients.



A WIDE RANGE OF ACTIVITIES

Management planning

Management planning is the key to successful service forestry. The process usually goes something like this. The forester first talks with the landowner to find out what he wants to do with his tract. Then an analysis of woodland condition is conducted. If the owner is agreeable and the tract lends itself to management, a plan is prepared. The typical plan is a simple document with a map and other relevant attachments designed to help owners make decisions in managing their forest. It summarizes results of the forester's analysis and spells out recommendations for particular practices that are consistent with sound forestry and owner needs. Plans are revised periodically to keep pace with changes in landowner desires, woodland condition and resource use (Fig. 3).

Each year more than 20,000 plans are prepared or revised for 1.2 million acres of forest land (Table 1). Few plans include more than 100 acres; the median covers about 30 (Fig. 4). Woodland reconnaissance, which is often done in conjunction with management planning, involves about 341,000 acres.

Timber stand improvement

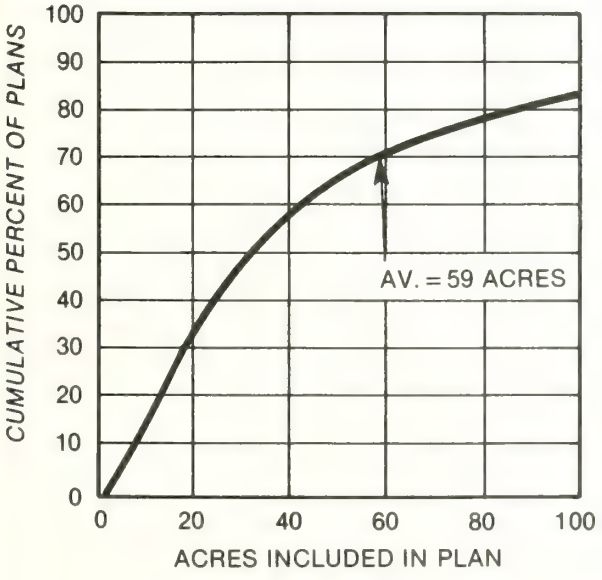
Foresters prescribe timber stand improvement (TSI) for woodlands in which nonmerchantable vegetation is impeding timber development. Unwanted trees that are too small or too low a grade to sell are eliminated to shift timber growth to fewer trees of better form and higher value. In some cases, competing vines are killed and undesirable branches are pruned to improve tree quality.

Figure 3.—On-the-ground planning—the key to successful forest management.

Table 1.—Summary of annual cooperative forestry assistance in the Northeast, 1977-78

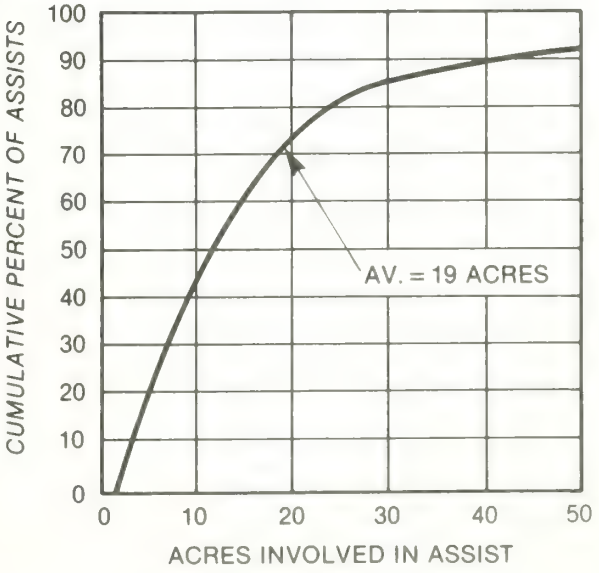
Activity	Number of cases	Acres involved	Percent of acres on which job is:	
			Done or likely to be done	Not done and not likely to be done
Management planning	20,100	1,183,800	100	—
Timber stand improvement	19,200	362,600	85	15
Timber sales and marketing	14,700	415,500	94	6
Tree planting	12,600	106,700	88	12
Wildlife habitat improvement	6,100	91,300	94	6
Site preparation	4,100	48,000	95	5
Recreation and esthetic improvement	2,700	47,600	98	2
Erosion control and streambank improvement	2,000	34,400	96	4
Pest or disease control	1,500	26,100	95	5
Natural regeneration establishment	1,100	27,600	97	3
Reconnaissance	5,800	341,100	100	—
Other	5,100	343,100	91	9

Figure 4.—Acres included in management plans.



While the primary goal is greater timber yields and dollar returns, special consideration is given trees with high nontimber values. For example, a large white oak cull with no potential for timber products but highly valuable as a source of food and habitat for wildlife might well be spared in a TSI operation. Our survey indicates that, annually, 19,000 land owners receive TSI advice and assistance for 363,000 acres of forest land. Only 10 percent of the jobs are larger than 45 acres. The median size TSI assist is 11 acres (Fig. 5).

Figure 5.—Acres involved in timber stand improvements assists.



Not all of the TSI work is completed. During the course of our study, service foresters were asked to separate jobs that were "done or likely to be done" from those that were "not done and not likely to be done." Results indicate that 15 percent of the TSI acres fall into the latter category (Table 1). This lower rate of accomplishment for TSI, compared to other activities, is not surprising; TSI is a relatively high-cost operation with a long wait until payoff. Many owners apply for forestry incentive payments (FIP) to help get the job done. Some are not approved for financial assistance and decide against TSI. Others, who start TSI jobs on their own, stop if they come to feel that the project is not worth the effort.

Timber sales and marketing assistance

Service foresters can be of great help in selling timber and other forest products. They select, mark, and estimate the volume of trees to be harvested and help the owner find reliable loggers and consultant foresters to negotiate sales. They do their best to satisfy landowner objectives while recommending cutting practices that are environmentally sound. Top dollar returns or optimum timber yields are not always of prime concern.

Each year the region's service foresters give timber sales and marketing assistance to some 15,000 landowners. The work involves 416,000 acres of forest and includes recommended harvests of 820 million board feet of sawtimber plus 460,000 cords of roundwood worth a total of $68.4 million.

Few sales and marketing assists involve more than 100 acres or more than $10,000 worth of timber. The median job involves 18 acres and $2,500 (Figs. 6-7). Almost 90 percent of the assists include sawtimber as a product; the median amount of sawtimber involved in these assists is 40 Mbf (Fig. 8). Only 25 percent of the assists include cordwood as a product; the median amount of cordwood involved is nearly 80 cords (Fig. 9). Study results show that, in general, sawtimber has a much better chance of being marketed than cordwood. Recent resurgence of the fuelwood market may change this somewhat.

Figure 6.—Acres involved in timber sales and marketing assists.

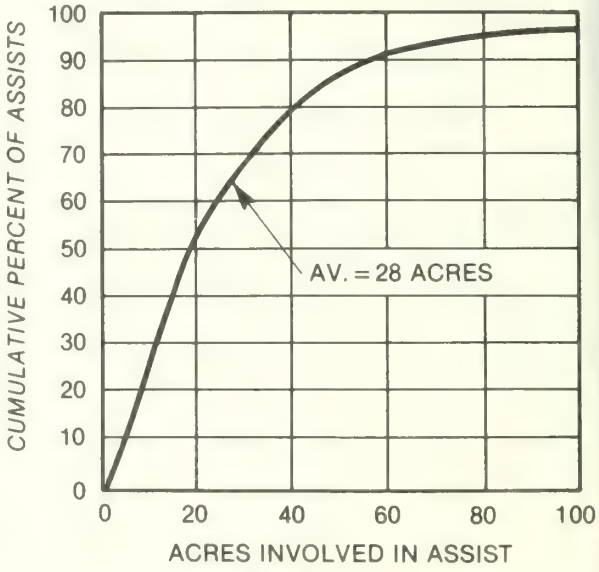
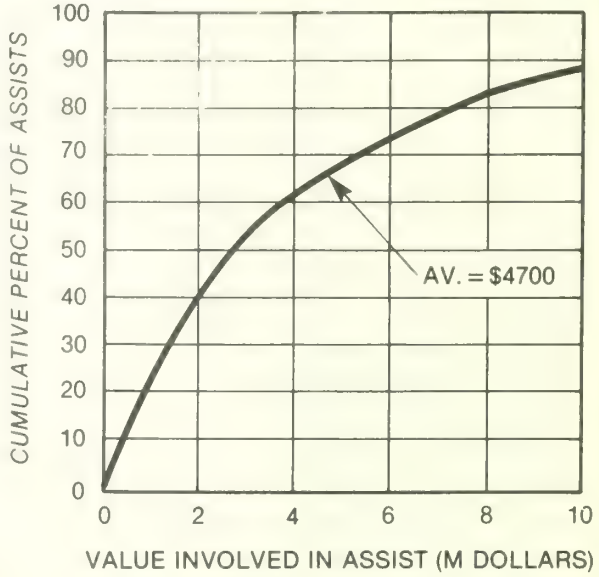


Figure 7.—Value involved in timber sales and marketing assists.



Gansner, David A., and Owen W. Herrick.
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Summarizes results of a recent inventory of service forester activities in 20 northeastern states. Each year some 500 local state foresters give one-half million hours of technical assistance and advice about the management of forest resources to nearly 50,000 woodland owners. Yearly on-the-ground help with activities ranging from timber sales to shade tree protection involves more than 2 million acres of nonindustrial private forest.

945.12

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Figure 8.—Mbf in sales and marketing assists involving sawtimber.

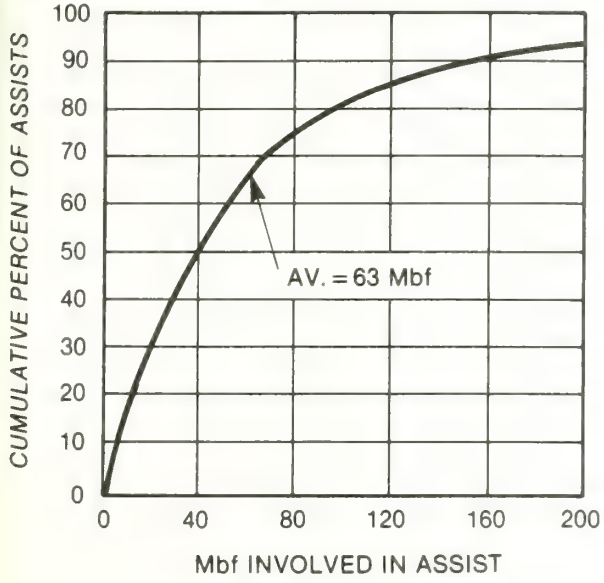
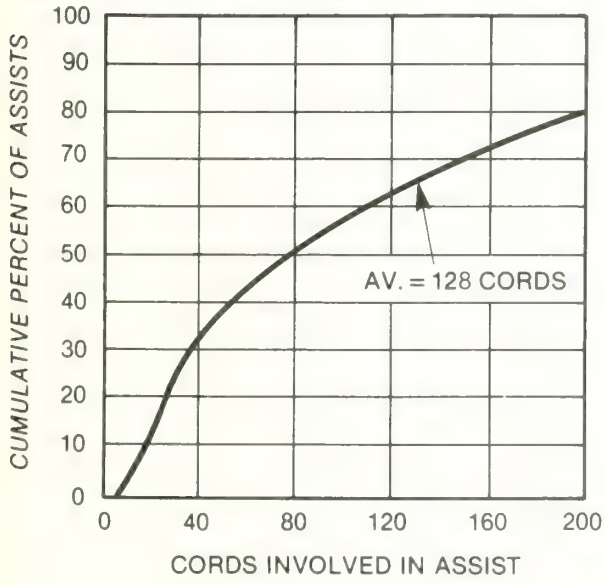


Figure 9.—Cords in sales and marketing assists involving cordwood.

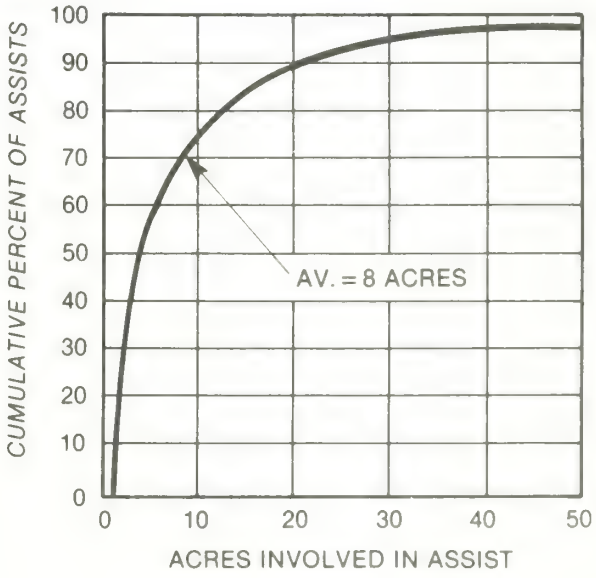


Tree planting

Tree planting assistance is another major activity of the service forester, involving more than 106,000 acres each year (Table 1). Nearly 13 thousand landowners receive this service. Foresters help the owner choose appropriate stock and planting sites and recommend species and spacing that are best suited to soil types and product objectives, and that minimize pest problems. They also help find reliable contractors to do the job.

Few assists involve plantations larger than 50 acres (Fig. 10); the median size is 3 acres. Site preparation assistance, often associated with tree planting, involves about 48,000 acres each year.

Figure 10.—Acres involved in tree planting assists.



Not just timber

A look at the overall service forester workload in the Northeast gives ready evidence that the region's forests are more than just "timber sheds." More and more requests for help are concerned with the protection and development of wildlife, recreation,

esthetic, soil, water, and other nontimber resources (Table 1, Figs. 11-13). Much of this work is done in conjunction with traditional timber management projects. It is common practice, for example, for a forester to leave productive mast trees when marking a stand for a timber sale (Fig. 14).

A few specific examples selected from case records will round out our summary of service forester activities. These include:

- Helping choose trees to leave for development of new homesites.
- Advising on the development of hiking and cross country ski trails.
- Assisting with prescribed burns for vegetation control.
- Helping set up protection zones for rare plant communities.
- Showing maple syrup producers how to manage their sugarbush and install tubing to collect sap.
- Instructing on the use of cultural practices for Christmas tree plantations.
- Helping lay out ponds and access lanes for fire protection.
- Helping owners understand and make use of forest tax laws.
- Advising against timber sales when trees are not financially mature.

Figure 11.—Acres involved in wildlife habitat improvement assists.

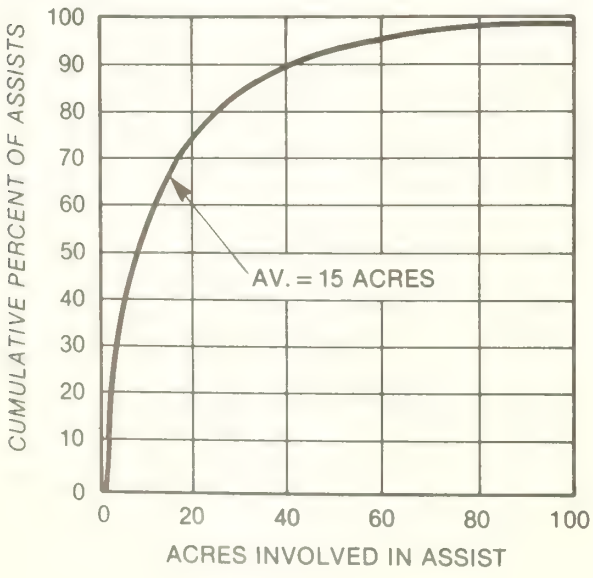


Figure 12.—Acres involved in recreation and esthetic improvement assists.

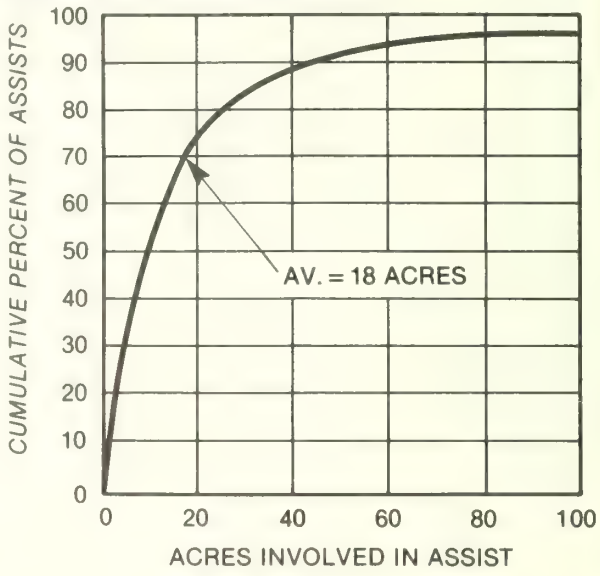


Figure 13.—Acres involved in erosion control and streambank improvement assists.

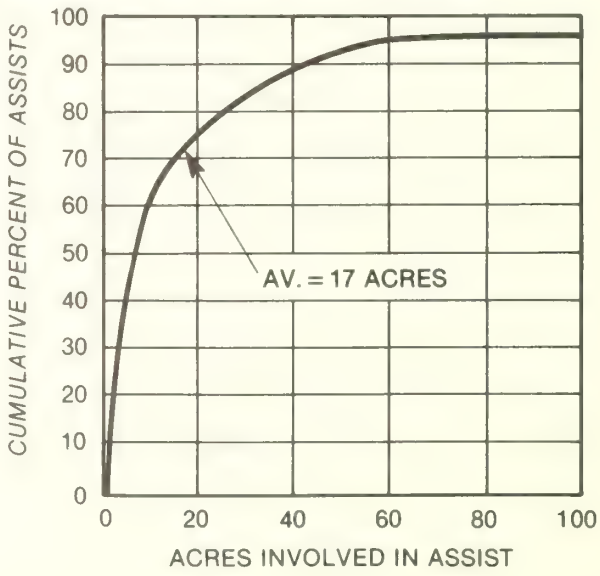


Figure 14.—This rascal's den was spared the saw in a TSI job.

A TYPICAL SERVICE FORESTER'S YEAR

Our study indicates that the median number of cases handled each year by the region's service foresters is 133. Using this median along with per-case estimates of activity results in the following profile of a typical service forester's year:

Gives 1,370 hours of technical assistance and advice to 133 forest-land owners. The work involves more than 5,600 of the 15,175 acres of forest land owned by these clients. Seventy percent of the people served are local residents and 53 percent of them have been assisted in previous years. Prepares or revises 54 management plans covering 3,205 acres of forest. Woodland reconnaissance is done on 918 acres. Gives timber sales and marketing assistance to 40 landowners for 1,130 acres. These assists involve a total of 1,250 cords of roundwood plus 2.2 million board feet of sawtimber worth $185,000. Fifty-two landowners receive timber stand improvement assistance for 984 acres. Tree planting help is received by 34 owners for 293 acres. Site preparation assistance is given for 133 acres. Helps 17 people with the development and protection of wildlife resources on 253 acres; 7 people with recreation and esthetic improvements on 133 acres; 5 people with erosion control and streambank protection on 93 acres; 4 people with pest and disease control on 66 acres; and 3 people with establishment of natural regeneration on 80 acres. In addition, 14 people receive help on 931 acres with a number of other activities such as access road and fire break development, Christmas tree culture, fencing, maple syrup production, and use of forest tax laws. Six of the 133 landowners served are referred to consultants for additional help.

ACKNOWLEDGMENTS

A special thanks to Don Seegrist, biometrics group leader, Northeastern Forest Experiment Station, who helped design our sample. Thanks also to Cliff Faulkner, Burl Ashley, Ken Lancaster, Rod Jacobs, and Bob Harrell of the Northeastern Area State and Private Forestry staff, who worked with some 150 state Cooperative Forestry Assistance supervisors and service foresters to collect the data.

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- Hamden, Connecticut, in cooperation with Yale University.
- Kingston, Pennsylvania.
- Morgantown, West Virginia, in cooperation with West Virginia University, Morgantown.
- Orono, Maine, in cooperation with the University of Maine, Orono.
- Parsons, West Virginia.
- Princeton, West Virginia.
- Syracuse, New York, in cooperation with the State University of New York College of Environmental Sciences and Forestry at Syracuse University, Syracuse.
- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.

Fisher, Edward L., Harry G. Gibson, and Cleveland J. Biller.
1980. Production and cost of a live skyline cable yarder tested in Appalachia. Northeast For. Exp. Stn., Broomall, Pa.
8 p., illus. (USDA For. Serv. Res. Pap. NE-465)

Logging systems that are profitable and environmentally acceptable are needed in Appalachian hardwood forests. Small, mobile cable yarders show promise in meeting both economic and environmental objectives. One such yarder, the Ecologger, was tested in the Jefferson National Forest near Marion, Virginia. Production rates and costs are presented for the system along with a discussion of the complete operation.

375.1(75)

Keywords: Timber harvesting, clearcutting, logging, cable yarding

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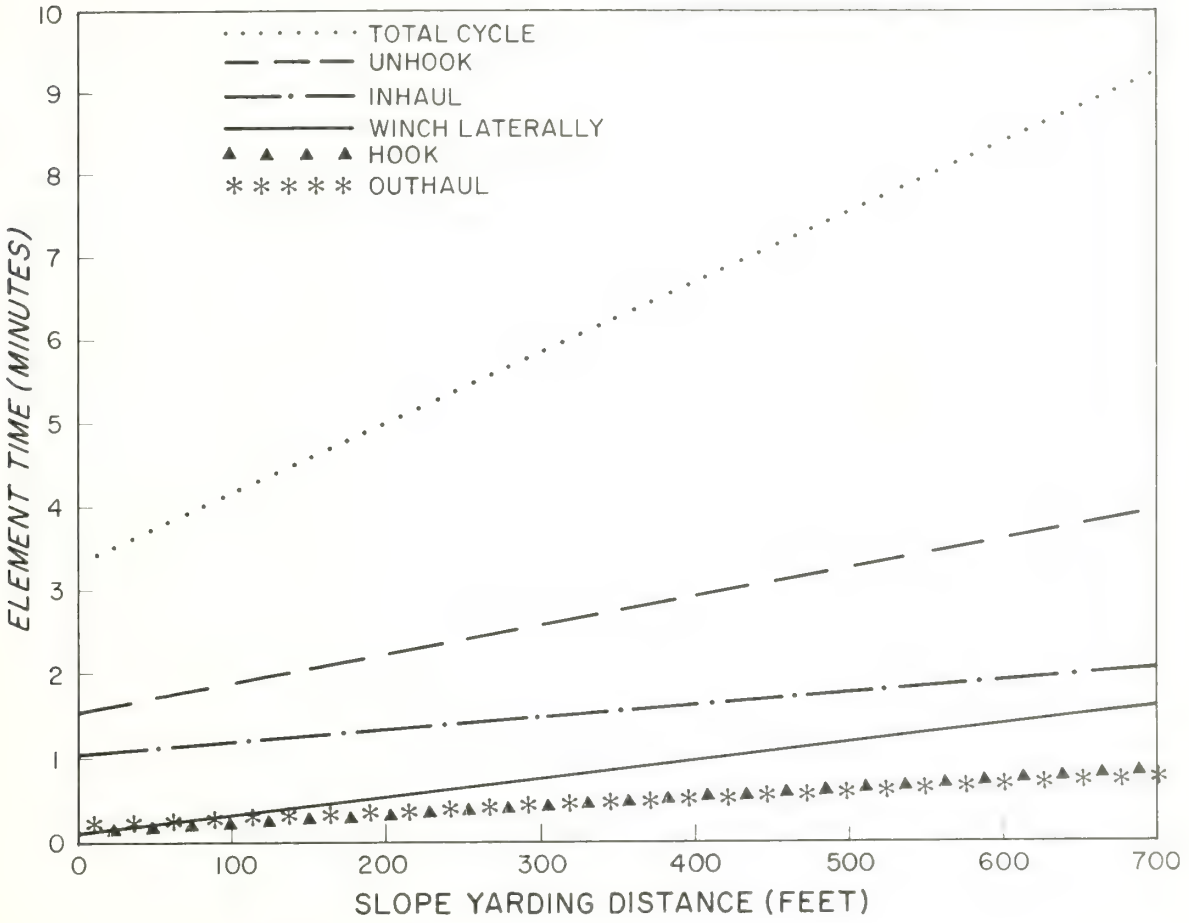
Figure 3.—Element time estimates as a function of yarding distance. (Lateral distance held constant at 30 feet and number of stems per turn at 1.35.)



The equations were chosen by comparing R^2 values and the level of significance of the variables. Yarding distance is significant in all phases. This would be expected in travel empty and travel loaded, but not in other elements. One reason for its high influence might be that as yarding distance increases, there is a slowing effect on all elements. That is, since travel empty and travel loaded consume more time, the other elements tend to slow down. Another reason might be an association of worker fatigue with longer yarding distances and increased cable pulling force needed at these distances.

Other significant variables are lateral yarding distance (in the hook and winch lateral equations) and the number of stems per turn (hook and unhook equations). The correlation coefficients are disappointingly low; however, low correlations are frequently observed in this field (Dykstra 1975). We expected the coefficients to be higher in the travel empty and travel loaded phases but believe the problem may be due in part to the slacking skyline. We found this problem in a similar trial of another slacking skyline machine, especially in the travel empty phase. Figure 3 contains a graph of each time element as a function of slope yarding distance (X1). Where lateral distance (X2) and logs per turn (X3) were also significant, average values of 30 feet and 1.35, respectively, were used for the graphs. Note the apparent effect of yarding distance on hook time.

Figure 4.—Aerial view of harvest area after logging shows only one major road.

Because the R^2 values are very low, the variable means of Table 1 may be the best indicators available, with the possible exception of the travel equations. In the latter, it appears that the time can be predicted to some degree by yarding distance and pieces per turn.

Cost analysis

A cost analysis was conducted using the time-study data and cost information supplied by the Jefferson National Forest and the contractor. These costs[2] do not reflect the delays due to control malfunctions and the absence of a skidder in the log decking operation.

Operation	*Cost (dollars per M of Doyle)*
Road construction	12.34
Yarding (including changing roads)	59.78
Moving yarder	2.39
Loading	16.23
Hauling	25.00
Total	113.74

[2] 1975 dollars.

CONCLUSION

Cable systems such as the Ecologger warrant further study in Appalachian timber stands. As the timber supply on moderate slopes decreases, cable logging will become more attractive. Although it appears that cable skidding may be more costly than ground skidding, it causes less damage to the environment. An aerial view of the site after logging (Fig. 4) shows only one major road; this is in contrast to the usual network of skidroads on similar slopes for ground skidding.

Environmental costs are difficult to determine, so each logging operation must be assessed individually. If the land manager chooses the more costly cable operation because of its lower environmental impact, one can assume that the environmental costs would equal or exceed the difference in harvesting costs between cable and traditional systems. The major problems evident during the test were a lack of available replacement parts, the absence of a swing skidder, and the inexperience of the logging crew. By reducing these problems, a logger could significantly improve his operation.

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APPENDIX

Ecologger Specifications

Basic carrier:	
Skidder	Tree Farmer C6D
Engine	GM 4:53 N Series, 130, 2,800 r/min
Hydraulic system:	
Pump capacity	25 Imp. gal/min, Working pressure 1,750 lb/in^2
Tires:	
Standard	18.4 x 34 (Can.), 23.1 x 26 (U.S.)
Spar:	
Tower	42-foot hydraulically raised 8- by 12-inch rectangular tubing with base pad
Guylines	4 independent hydraulically driven—200 feet of 3/4-inch cable on each drum
Controls	Digital remote control backup umbilical cord
Winch system:	
skyline drum	Direct coupled—automatic 2 speed Line speed: 750 ft/min Maximum line pull: 23,400 lb Capacity: 100 feet—11/16-inch rope
Mainline drum	Maximum line pull: 8,500 lb—base of drum Line speed: 950 ft/min—single speed Capacity: 1,540 feet—9/16-inch rope
Strawline drum	Maximum line pull: 2,500 lb—base of drum Line speed: 2,500 ft/min—single speed Capacity: 1,800 feet—5/16-inch rope
Carriage	Maki with stop at bottom of skyline
Weight	Approximately 28,000 lb without cable

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- University Park, Pennsylvania, in cooperation with the Pennsylvania State University.
- Warren, Pennsylvania.

By John E. Baumgras

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NORTHEASTERN FOREST EXPERIMENT STATION
370 REED ROAD, BROOMALL, PA 19008

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MANUSCRIPT RECEIVED FOR PUBLICATION 5 JUNE 1980

Abstract

To determine the yield of whole-tree biomass available from thinning Allegheny hardwoods, 64 sample plots were thinned in poletimber—small sawtimber stands located near Elkins, West Virginia. Biomass yields were derived from cut stand data and whole-tree weight equations, and averaged approximately 60 green tons per acre. Regression equations are given for predicting per-acre green-weight and dry-weight biomass yields from the square feet of basal area and the number of trees removed per acre of thinning.

MILLIONS OF ACRES of eastern hardwood poletimber—small sawtimber stands represent a major forest resource. The thinnings and improvement cuttings that are needed to increase the production of quality sawtimber from the stands can supply immense volumes of fiber, fuel, and sawn products. However, the resource has been underutilized because of inadequate markets for small logs and a lack of efficient systems for harvesting and processing small trees from thinnings. Productivity of the stands is below potential, and large volumes of potential wood products are lost to mortality.

A study of the product yields available from hardwood thinning was conducted by the Northeastern Forest Experiment Station's Forestry Sciences Laboratory at Princeton, West Virginia. Initial results from the study showed that roundwood yields from thinnings were 1,260 ft^3 per acre from Allegheny hardwoods, and 1,453 ft^3 from oak-hickory stands. Product yields included 17 percent factory grade sawlogs, 40 percent sawbolts, and 43 percent pulpwood and firewood (Craft and Baumgras 1978 and 1979).

Wood fiber from whole-tree chips is an alternative product available from hardwood thinnings. The need for more complete tree utilization has led to the development of whole-tree chippers that are becoming commonplace throughout much of the eastern United States. Brenneman and others (1978) reported that whole-tree utilization can increase yields from Appalachian hardwood stands by more than 30 percent over those of conventional roundwood harvesting. Martin (1977) reported a 35 percent increase when whole-tree chip yields were compared to roundwood yields from a cove hardwood stand. Application of this technology would result in significantly greater yields than the roundwood yields we have reported. The recent development of whole-tree weight equations has made it possible to estimate biomass yields available from thinnings, and to develop the biomass predictors presented in this report.

STUDY AND METHODS

Nine Allegheny hardwood stands along a 30-mile section of Middle Mountain near Elkins, West Virginia, were sampled. The elevation of these stands ranged from 3,000 to 3,800 feet. The combined species composition of all stands sampled by percent basal area was: black cherry (*Prunus serotina* Ehrh.), 42 percent; maple (*Acer saccharum* and *Acer saccharinum*), 31 percent; birch (*Betula alleghaniensis* and *Betula lenta*), 8 percent; beech (*Fagus grandifolia*), 7 percent; cucumbertree (*Magnolia acuminata*), 5 percent; white ash (*Fraxinus americana*), 3 percent; and other species, 4 percent.

Sampled stands represented overstocked poletimber—small sawtimber stands that occupied medium to good quality sites, and stands that should be thinned to increase production of quality sawtimber. Within these limits, we sampled a variety of stocking conditions and site qualities.

Sixty-four 1/10-acre plots were thinned. Initial stocking and species composition on each plot were determined by recording

dbh and species for each tree that was 1.0 inch dbh or larger. The Allegheny hardwoods stocking guide published by Roach (1977) was used to determine the appropriate residual stocking for each plot. Because only overstocked stands were sampled, initial stocking exceeded 100 percent. Thinning reduced stocking to between 60 and 65 percent of full stocking.

Initial basal area of the sampled stands ranged from 132 ft^2 per acre to 184 ft^2 per acre. Residual basal area ranged from 77 ft^2 per acre to 113 ft^2 (Table 1). To create the canopy openings needed to stimulate crown growth on crop trees, the thinning removed a few dominant and codominant trees. However, to increase the mean stand diameter, thinning concentrated on trees in the lower diameter classes, and thinning increased the mean stand diameter an average of 2.3 inches.

Green-weight and dry-weight plot yields were estimated by summing the predicted whole-tree weights of all cut trees 1.0 inch dbh and larger. Tree weight predictions were made using mixed hardwood equations from three separate sources (Brenneman 1978, Monteith 1979, and Wartluft 1977). Different tree weight equations were used to determine how much thinning yield estimates would vary because of differences in the tree weight equations. Brenneman's and Wartluft's equations were developed from trees sampled in West Virginia; Monteith sampled trees in New York. All equations were based on samples that included those species removed from the thinning plots. However, Brenneman's sample included a species mixture most like that found on the thinning plots.

Each of the tree weight equations listed below uses dbh to predict whole-tree weight. The predicted weight, W, is expressed in pounds. Dbh, the independent variable, is measured in inches.

Tree weight equations:

Green

Brenneman $W = 4.3426\ dbh^{2.4594}$

Monteith $W = 20.2255 - 30.9727\ dbh + 15.5746\ dbh^2$

Wartluft $W = 4.7084\ dbh^{2.3938}$

Dry

Brenneman $W = 2.4544\ dbh^{2.4627}$

Monteith $W = 12.1798 - 18.7732\ dbh + 9.3177\ dbh^2$

Wartluft $W = 2.6011\ dbh^{2.4264}$

Plot yields and stocking parameters were converted to per-acre values. Various regression analyses were then performed to examine the relationship between per-acre biomass yields and certain stand parameters. Plot yield estimates, based on Brenneman's tree weight equations, were used in the regression analyses because of the similar species distribution and location of Brenneman's sample to the thinning plots. For the regression analyses each sample plot represented one observation.

Table 1.—Stocking of sample stands, trees ⩾ 1.0 inch dbh

Stand	Number of sample plots	Basal area per acre			Trees per acre			Mean dbh		
		Initial stand	Cut stand	Residual stand	Initial stand	Cut stand	Residual stand	Initial stand	Cut stand	Residual stand
		Square feet			*Number*			*Inches*		
1	9	148	71	77	517	384	133	7.2	5.8	10.3
2	8	151	75	76	481	370	111	7.6	6.1	11.3
3	8	180	70	110	535	321	214	7.9	6.3	9.7
4	6	140	49	91	790	508	282	5.7	4.2	7.7
5	6	147	59	88	837	582	255	5.7	4.3	7.9
6	6	152	53	99	813	548	265	5.8	4.2	8.3
7	7	132	55	77	741	471	270	5.7	4.6	7.2
8	6	155	54	101	463	278	185	7.8	6.0	10.0
9	8	184	71	113	684	434	250	7.0	5.5	9.1

The objective was to see if reliable biomass yield predictors, based on common available parameters—basal area and trees per acre, could be developed to provide a reliable alternative to the process of summing individual tree weight estimates.

RESULTS

Biomass yields

For each tree weight equation, the average estimated whole-tree biomass yield from all plots was:

Tree weight equation	*Green tons/acre*	*Dry tons/acre*
Brenneman	63.0	35.9
Monteith	65.4	39.0
Wartluft	59.8	35.3

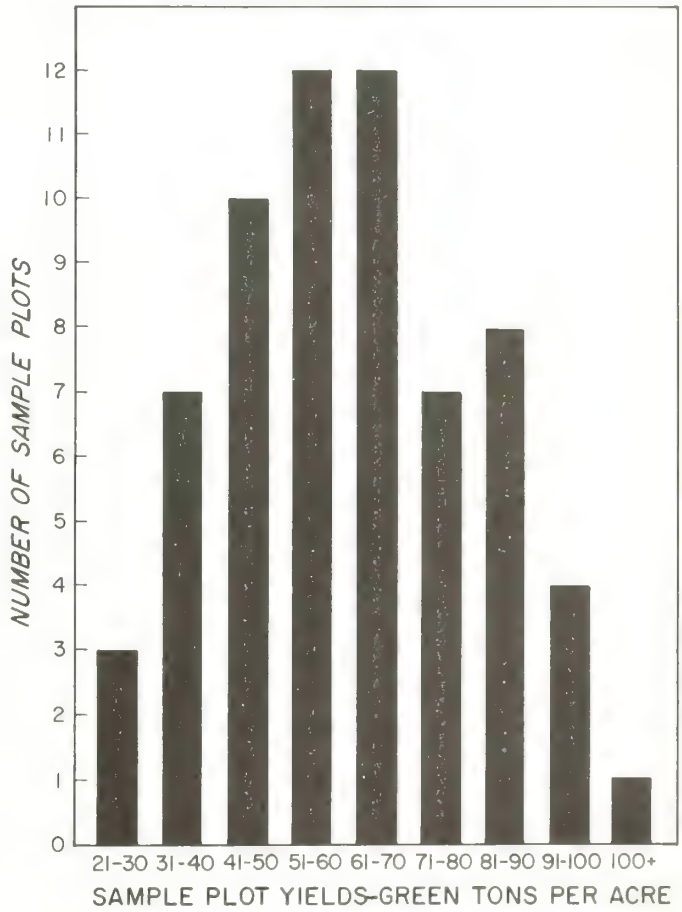
Monteith's tree weight equations provided the highest plot yield estimates, and Wartluft's the lowest (about 9 percent lower than Monteith's). For trees 3 to 10 inches dbh, Monteith's equation results in estimates that are higher than the other two equations (Table 2). Since most cut trees on the thinning plots were less than 10 inches dbh, Monteith's equation gave the highest plot yield estimates.

Table 2.—Predicted whole-tree green weight, in pounds, from tree weight regression equations

Tree dbh (inches)	Source of tree weight equation		
	Brenneman	Monteith	Wartluft
1	4	5	5
2	24	21	25
3	65	67	65
4	131	145	130
5	227	255	222
6	356	395	343
7	520	566	496
8	722	769	683
9	965	1,003	906
10	1,251	1,268	1,166
11	1,581	1,564	1,465
12	1,958	1,891	1,804

The variability of sample plot yields is shown in Figure 1. Estimates of weight yield for the thinned plots based on Brenneman's tree equation ranged from 26 green tons per acre to more than 100 green tons per acre. Yields estimated from Monteith's and Wartluft's equations showed almost an identical range.

Figure 1.—Frequency distribution of sample plot weight yields (estimated from Brenneman's tree weight equation).



The results from the regression analyses show that most of the variation between estimated plot yields can be explained by the amount of basal area removed in thinning

(Table 3). By adding the number of cut trees per acre to the thinning yield model as a second independent variable, the standard error of the estimate is reduced by more than 30 percent (Table 3). This reduction in the error is linked to the relationship of basal area, trees per acre, and mean stand diameter. For a given amount of basal area removed, the mean diameter of the cut trees decreases as the number of trees cut increases. Smaller trees provide less biomass per square foot of basal area. For example, from Brenneman's equation the relationship between tree diameter and green weight per square foot of basal area is as follows:

Dbh	*Pounds/ft²*
2	1,091
3	1,327
4	1,506
5	1,669
6	1,816
7	1,948
8	2,069
9	2,183
10	2,294

Table 3.—Coefficients and statistics for thinning biomass yield prediction equations developed from Brenneman's tree weight equations

Regression equations and coefficients	Statistics	
	R^2	Standard error of estimate
$GW = 0.99793(X_1)$	0.945	5.37
$DW = 0.56784(X_1)$	.944	3.08
$GW = 1.15127(X_1) - 0.02345(X_2)$	.976	3.58
$DW = 0.65570(X_1) - 0.01344(X_2)$	.976	2.05

GW = tons/acre, green weight from trees 1.0 inch dbh and larger.

DW = tons/acre, dry weight from trees 1.0 inch dbh and larger.

X_1 = basal area cut/acre, trees 1.0 inch dbh and larger.

X_2 = trees cut/acre 1.0 inch dbh and larger.

Therefore, the trees-per-acre coefficient has a negative sign that decreases the weight estimate as the number of trees cut per acre increases. For example, if 60 ft^2 of basal area and 300 trees are cut per acre, the estimated yield is 62 green tons per acre. If the basal area cut remains at 60 ft^2, and the number of trees cut per acre is increased to 600, the estimated yield is reduced to 55 green tons per acre (Table 4).

If only basal area removed is used to predict weight yields, the results will be most reliable when the mean diameter of the cut stand is close to the average, which was 5.2 inches dbh, for all stands sampled. However, for preliminary surveys, basal area removed provides an adequate estimate of thinning biomass yields. To make these estimates, the stand yield equations in Table 3 can be applied directly to stand data, or these equations can be used to develop a yield table similar to that in Table 5. For a quick estimate, a rule-of-thumb that can be used is 1 green ton for each square foot per acre of basal area removed.

A more accurate weight yield estimate can be obtained from the stand yield models by using both basal area and trees per acre. This reduces the error due to variations in cut stand diameter (Table 3). These equations can also be used to develop biomass yield tables (Table 4).

To use the weight yield equations or tables, make a reliable estimate of either basal area, or basal area and the number of trees to be cut per acre of thinning. Although the biomass yield equations were developed from fixed area plot yields, they can be applied to cut stand parameters obtained from either variable radius prism plots or fixed area plots. Sample plot data can be summarized for a particular stand, and then the average stand parameters can be used with the yield equations or tables to predict thinning weight yields. However, these results should be applied only to stands with mean cut tree diameters within the range of the plots sampled in this study—3.0 to 9.0 inches dbh. These yield models might not provide realistic results when used outside this diameter range.

Baumgras, John E.
1980. **Biomass yields from Allegheny hardwood thinning.** Northeast. For. Exp. Stn., Broomall, Pa.
7 p., illus. (U.S. Dep. Agric. For. Serv. Res. Pap. NE-466)

To determine the yield of whole-tree biomass available from thinning Allegheny hardwoods, 64 sample plots were thinned in poletimber—small sawtimber stands located near Elkins, West Virginia. Biomass yields were derived from cut stand data and whole-tree weight equations, and averaged approximately 60 green tons per acre. Regression equations are given for predicting per-acre green-weight and dry-weight biomass yields from the square feet of basal area and the number of trees removed per acre of thinning.

333:539—0155

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Table 4.—Biomass yield table using basal area and trees cut per acre to predict thinning yields from trees ≥ 1.0 inch dbh (based on yield model developed from Brenneman's tree weight equation).

Number of trees cut per acre	Basal area removed in thinning, square feet per acre						
	30	40	50	60	70	80	90
	Green tons/acre						
100	32	44	55	67	78	90	101
200	30	41	53	64	76	87	99
300	28	39	51	62	74	85	97
400	25	37	48	60	71	83	94
500	23	34	46	57	69	80	92
600	20	32	43	55	67	78	90
700	18	30	41	53	64	76	87
800	16	27	39	50	62	73	85
	Dry tons/acre						
100	18	25	31	38	45	51	58
200	17	24	30	37	43	50	56
300	16	22	29	35	42	48	55
400	14	21	27	34	41	47	54
500	13	20	26	33	39	46	52
600	12	18	25	31	38	44	51
700	10	17	23	30	36	43	50
800	9	15	22	29	35	42	48

Table values within box rules correspond to the range of sample data used to develop the table.

Table 5.—Biomass yield tables for using basal area to predict thinning biomass yield, tons per acre

Basal area removed (ft^2/acre)	Predicted biomass yield	
	Green weight	Dry weight
20	20	11
30	30	17
40	40	23
50	50	28
60	60	34
70	70	40
80	80	45
90	90	51

Trees per ton of biomass

The mean diameter of the cut trees affects harvesting efficiency as well as biomass yields. As tree diameter decreases, the number of cut trees per ton of biomass increases. Thus, more trees must be cut, skidded, and chipped per ton of chip yield. Therefore, the mean diameter of the cut stand is an important consideration in harvesting, especially in thinning operations that generally concentrate on the smaller diameter trees.

Mean stand diameter (MSD) can be calculated from basal area (BA) and trees per acre (TA) using the following equation:

$$MSD = \sqrt{\frac{BA}{TA}}\,(183.35)$$

Regression equations for predicting the number of trees per green ton were developed from the estimated biomass yields and cut stand parameters on each plot. The equation, $Y = aX^b$, uses mean cut stand diameter as X. The coefficients and statistics are:

Source of tree-weight equation	Coefficients		Statistics	
	a	*b*	R^2	Standard error
Brenneman	289.04	-2.258	0.991	0.393
Monteith	266.74	-2.239	.993	.203
Wartluft	287.66	-2.226	.997	.348

The number of cut trees per ton of biomass harvested, predicted by the regression developed from Brenneman's tree weight equation, is shown below. When mean stand diameter drops below 6 inches dbh, the number of trees per ton rapidly increases. For example, if the mean stand diameter is only 4 inches, more than 12 trees must be harvested per ton of biomass, versus only 2 trees at 9 inches.

Mean stand diameter (inches)	*Number of cut trees per ton of biomass harvested*
3	24.2
4	12.6
5	7.6
6	5.1
7	3.6
8	2.6
9	2.0
10	1.6

DISCUSSION

Predicting thinning biomass yields by the basal area or basal area and number of trees removed provides a simple, yet reliable alternative to summing tree weights estimated from cut tree diameters. The error terms for these models include only the variance between the sum of the estimated tree weights and the predicted sum of the estimated tree weights. Because the stand yield models were developed from estimated tree weights, there is an added source of error in the estimates provided by these models—the error in the estimated tree weights. Because of the relatively low error in the tree weight models, this additional source of error should not significantly affect the reliability of the stand yield models. Furthermore, similar error would also be encountered when summing estimated individual tree weights.

The tree weight equations developed by Brenneman, Monteith, and Wartluft provided differing plot weight yield estimates. However, the differences in estimated plot yields attributable to the tree weight equations were relatively minor compared to the differences between plots related to variations in stocking. Individual plot yields differed by as much as 75 green tons per acre (Figure 1). However, the difference in individual plot yields between tree weight equations averaged less than 6 green tons per acre, and exceeded 9 tons on only four plots.

The thinning yield models were developed from mixed or combined hardwood tree weight equations. These models should provide reliable results when applied to stands with the mixture of species common to Allegheny hardwood or northern hardwood timber types.

In the fully stocked Allegheny hardwood stands that were sampled, thinnings yielded approximately 60 tons of whole-tree biomass per acre. Millions of acres of eastern hardwoods could be thinned, and the biomass available from thinning represents a tremendous supply of wood fiber or fuel.

New forest mensuration techniques and new methods of harvesting and processing small trees from thinnings will be required to utilize this resource. The thinning yield models that were developed can aid in the development of this technology. These models can be used with conventional cruising methods to predict thinning yield weights and values. Stand or tract weight yield predictions can also be used in the determination of harvesting cost estimates and in the selection of efficient harvesting systems.

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MIROSLAW M. CZAPOWSKYJ
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Foliar Nutrient Status of Young Red Spruce and Balsam Fir in a Fertilized Stand

FOREST SERVICE RESEARCH PAPER NE-467
1980

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE
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Abstract

Average dry weight and nutrient levels in current foliage from red spruce and balsam fir seedlings and saplings in the understory of a 25-year old aspen and birch stand were observed 3 years after N, P, and lime treatments were applied. Elemental concentrations were plotted as a function of needle weight and quantity of element per needle. This allows interpretation of treatment effect on overall nutrient levels for both concentration and quantity of each element in the foliage. In balsam fir, dry weight per needle was significantly increased by N fertilizer. Nitrogen also significantly affected levels of ash, N, P, K, Ca, Fe, Mn, Zn, and Na in balsam fir foliage. In red spruce, dry weight per needle, N, and Fe levels all responded to N fertilizer; P fertilizer affected P foliar concentration and lime significantly affected Mn levels. In both species there were significant interactions among the N, P, and lime treatments, indicating that response to one element varied according to the other elements added simultaneously. Balsam fir needles were heavier and contained higher levels of nutrients than red spruce needles. The magnitude of changes in elemental levels was generally greater for balsam fir than for red spruce.

INTRODUCTION

THERE IS INCREASING CONCERN that site productivity of spruce-fir forests in Maine may be diminished by complete-tree utilization. Current interest in forest fertilization, and current research on nutritive values of spruce and fir foliage for the spruce budworm population dynamics, have intensified the need for more accurate estimates of tree responses to fertilizer application.

Foliage analysis is a sensitive and accepted method of assessing the ability of soils to supply nutrients for adequate tree growth. In 1974 we established a study to determine if a stand with an aspen-birch-maple overstory and a scattered spruce and fir understory would respond to treatments with lime, nitrogen, and phosphorus applied singly and in combination following a precommercial thinning. The responses of the overstory hardwoods to fertilizer and lime were documented earlier (Czapowskyj and Safford 1979, Schmitt et al. 1979).

In this paper we report the concentration and content of nutrients in the current-year foliage of red spruce and balsam fir as related to fertilizer treatments applied three growing seasons earlier.

STUDY

The study was established in Washington County, Maine, on land owned by Georgia Pacific Corporation. The stand originated following a wildfire in 1952. The overstory consists primarily of aspen (*Populus tremuloides* Michx. and *P. grandidentata* Michx.), 78 percent of the basal area, and paper birch (*Betula papyrifera* Marsh.), 14 percent of the basal area. The soils are well- and moderately well-drained Haplorthods. For a more detailed description of the study area, the origin and composition of the forest overstory, and soil characteristics see Czapowskyj and Safford (1979). In the present study we observed the effects of lime and fertilizer and the foliage of the understory stand consisting of red spruce (*Picea rubens* Sarg.), white spruce (P. glauca (Moench) Voss), and balsam fir (*Abies balsamea* (L.) Mill.) (Table 1).

Twenty-four 20- by 20-m plots with 7-m wide isolation strips were laid out. Because of the nature of the landscape, some plots were on well-drained soils, some on moderately well-drained soils, and some plots had both. Lime and fertilizer treatments were assigned randomly among plots as follows:

- Control (C)
- Lime (L): 4,480 kg/ha; 100 percent $CaCO_3$ equivalent as ground limestone providing 1,749 kg Ca and 27 kg Mg/ha.
- Nitrogen (N): 448 kg/ha of elemental N, as 46-0-0 urea.
- Phosphorus (P): 112 kg/ha of elemental P as 0-45-0 triple superphosphate. In addition to P, the fertilizer contained 12 percent Ca (±30 kg/ha).
- All combinations NL, PL, NP, NPL—for a total of eight treatments replicated three times.

Lime was broadcast by hand on the soil surface in the fall of 1974. Phosphorus and one-half of the nitrogen were broadcast in June 1975; the remaining nitrogen was added in August 1975.

Foliage sampling and analysis

The samples of red spruce and balsam fir foliage were collected in early September 1977—three growing seasons after the stand was fertilized.

Sampling. Three trees of each species were selected randomly to represent each treatment and replication. The trees were less than 1.37 m tall and were free of any damage caused by spruce budworm (*Choristoneura fumiferana* (Clem.)) infestation. Twigs with

Table 1.—Characteristics of a 15-year-old aspen-birch spruce-fir stand before fertilization (average of three replications)

Species		Stand characteristics					
		Trees/ha		Height	Dbh	Basal area/ha	
		Number	*Percent*	*m*	*cm*	m^2	*Percent*
Overstory							
Aspen, birch, other hardwoods		1512	74	6.7	6.4	4.9	98
Understory							
Red spruce	⩾ 1.37m	67	3	2.34	1.80	0.04	0.7
	< 1.37m	135	7	.75	—	—	—
Balsam fir	⩾ 1.37m	60	3	2.75	2.65	0.05	0.9
	< 1.37m	139	7	.67	—	—	—
Other softwoods	⩾ 1.37m	10	1	2.45	2.17	0.02	0.4
	< 1.37m	100	5	.74	—	—	—
Total or average of softwoods		511	26	⩾ 1.37 $\bar{x}$ = 2.53 < 1.37 $\bar{x}$ = 0.72	$\bar{x}$ = 2.20	0.11	2

current-year needles were collected from upper crown portions. Equal quantities of foliage of each of the three trees per species were combined for a total of 24 composite samples of red spruce and 23 of balsam fir (one plot had no balsam fir). Samples were dried at 65°C to constant weight, ground to pass a 20-mesh screen, and prepared in duplicate for chemical analysis.

Chemical analysis. The samples were dry ashed at 500°C; the ash content was determined gravimetrically. The ash was taken up in dilute HC1 and calcium (Ca), magnesium (Mg), potassium (K), sodium (Na), manganese (Mn), zinc (Zn), and iron (Fe) were determined by atomic absorption. Nitrogen (N) and total phosphorus (P) were determined in Kjeldahl digests with an auto analyzer.

All analyses were performed on the oven-dry (65°C) samples. Foliar nutrients are expressed both in concentration (percent or ppm) and actual content (mg per 1,000 needles).

Statistical analysis

For each species, ash, oven-dry weight, nutrient concentration, and content were analyzed as dependent variables by analysis of variance. The experimental design was a complete factorial with three fertilizer treatments: lime, nitrogen, and phosphorus. Each factor had two levels: absent and present. Each treatment was replicated three times except for balsam fir which had only two replicates for the lime treatment.

Because main effect factors have only two levels, mean separation techniques were not necessary. Factorial analysis of variance and the F test were used to determine significance of the main effects of each nutrient treatment as well as interaction among nutrient elements (Mendenhall 1968).

RESULTS

Mean needle weight and nutrient levels in the foliage of these understory red spruce trees (Tables 2 and 3) are generally consistent with findings of Schomaker (1973) and Safford et al. (1977) in overstory dominant and codominant red spruce. Average needle weight, nitrogen concentration, and potassium concentration of control foliage differed the most. In this study, needles from control trees weighed 1.72 mg per needle compared with 2.5 mg per needle reported by Safford et al. (1977); N concentration in this study was 0.82 percent while Schomaker (1973) and Safford et al. (1977) reported 1.03 percent. Potassium concentration of foliage from this study averaged 0.49 percent compared with 0.92 percent reported by Schomaker (1973) and 0.98 percent reported by Safford et al. (1977).

Mean needle weight and nutrient levels in the balsam fir trees in this study (Tables 4 and 5) are very close to those reported for similar-size trees by Timmer and Stone (1978) and Czapowskyj (1979); N concentration at 0.95 percent in this study was somewhat lower than that reported by either Timmer and Stone (1978) at 1.5 percent or Czapowskyj (1979) at 1.4 percent.

Table 2.—Sample means and standard deviations of red spruce foliar ash and nutrient concentrations three growing seasons after fertilization.

Treatment	Ovendry weight of 1,000 needles	Ash	Nutrient								
			N	P	Ca	K	Mg	Mn	Na	Fe	Zn
	gm	*Percent*							*ppm*		
Control	1.72 (0.43)[a]	2.37 (0.60)	0.82 (0.08)	0.16 (0.02)	0.31 (0.13)	0.49 (0.13)	0.07 (0.04)	0.16 (0.10)	282 (99)	42 (19)	56 (52)
N only	1.74 (0.22)	2.22 (0.16)	1.00 (0.18)	0.14 (0.02)	0.27 (0.07)	0.50 (0.09)	0.05 (0.02)	0.13 (0.01)	252 (75)	66 (24)	35 (26)
P only	1.62 (0.26)	2.33 (0.30)	0.75 (0.12)	0.18 (0.02)	0.28 (0.03)	0.61 (0.06)	0.06 (0.02)	0.14 (0.02)	271 (12)	45 (21)	32 (9)
Lime only	1.33 (0.13)	2.42 (0.14)	0.78 (0.05)	0.16 (0.01)	0.30 (0.10)	0.53 (0.08)	0.06 (0.02)	0.11 (0.01)	239 (103)	46 (15)	66 (58)
N+P	1.89 (0.21)	2.24 (0.60)	1.18 (0.16)	0.16 (0.02)	0.26 (0.07)	0.46 (0.12)	0.05 (0.02)	0.09 (0.02)	247 (50)	46 (13)	50 (45)
Lime + N	2.19 (0.27)	2.52 (0.22)	1.05 (0.08)	0.15 (0.01)	0.25 (0.01)	0.62 (0.04)	0.05 (0.02)	0.08 (0.01)	339 (144)	40 (3)	32 (13)
Lime + P	1.60 (0.20)	2.53 (0.20)	0.70 (0.04)	0.18 (0.02)	0.29 (0.02)	0.56 (0.02)	0.07 (0.01)	0.10 (0.01)	201 (91)	33 (11)	63 (77)
Lime + N+P	1.78 (0.24)	1.99 (0.49)	1.07 (0.10)	0.16 (0.02)	0.33 (0.03)	0.45 (0.02)	0.06 (0.01)	0.06 (0.01)	229 (78)	58 (23)	19 (4)

[a]Standard deviation in parenthesis.

Table 3.—Sample means and standard deviations of ash and nutrient contents for red spruce foliage three growing seasons after treatment.

Treatment	Ash	Nutrient								
		N	P	Ca	K	Mg	Mn	Na	Fe	Zn
	mg/1000 needles									
Control	42.0 (19.7)[a]	14.1 (4.2)	2.8 (0.9)	5.7 (3.8)	8.2 (1.7)	1.4 (1.1)	2.4 (1.2)	0.47 (0.11)	0.08 (0.05)	0.11 (0.13)
N only	38.8 (7.5)	17.3 (3.6)	2.5 (0.5)	4.7 (1.2)	8.7 (2.1)	0.8 (0.2)	2.3 (0.5)	0.43 (0.08)	0.11 (0.05)	0.06 (0.04)
P only	38.0 (9.4)	12.3 (3.9)	3.0 (0.7)	4.6 (0.8)	9.9 (2.4)	1.0 (0.4)	2.3 (0.7)	0.44 (0.07)	0.08 (0.04)	0.05 (0.02)
Lime only	32.1 (1.8)	10.3 (0.4)	2.1 (0.3)	3.9 (0.9)	7.0 (0.7)	0.8 (0.2)	1.5 (0.2)	0.32 (0.15)	0.06 (0.02)	0.09 (0.08)
N+P	42.8 (14.3)	22.0 (0.7)	2.9 (0.4)	5.0 (1.8)	8.6 (1.7)	1.0 (0.4)	1.7 (0.5)	0.47 (0.13)	0.08 (0.02)	0.10 (0.09)
Lime + N	54.9 (2.1)	23.0 (1.8)	3.2 (0.3)	5.5 (0.7)	13.6 (0.8)	1.0 (0.4)	1.8 (0.2)	0.73 (0.26)	0.09 (0.02)	0.07 (0.03)
Lime + P	40.6 (6.4)	11.2 (1.3)	2.8 (0.2)	4.7 (0.3)	9.0 (1.3)	1.1 (0.3)	1.6 (0.3)	0.33 (0.19)	0.05 (0.02)	0.11 (0.15)
Lime + N+P	34.7 (6.1)	19.2 (4.4)	2.8 (0.2)	5.8 (0.8)	8.1 (1.0)	1.1 (0.2)	1.1 (0.2)	0.41 (0.14)	0.11 (0.06)	0.03 (0.01)

[a] Standard deviation in parenthesis.

Table 4.—Sample means and standard deviations of balsam fir foliar ash and nutrient concentrations three growing seasons after fertilizing.

Treatment	Ovendry weight of 1,000 needles	Ash	Nutrient								
			N	P	Ca	K	Mg	Mn	Na	Fe	Zn
	gm	*Percent*							*ppm*		
Control	3.45 (0.59)[a]	3.32 (0.18)	0.95 (0.13)	0.19 (0.03)	0.51 (0.02)	0.61 (0.06)	0.08 (0.02)	0.16 (0.02)	174 (60)	35 (4)	48 (4)
N only	4.74 (0.53)	2.86 (0.50)	1.22 (0.10)	0.16 (0.01)	0.57 (0.16)	0.45 (0.21)	0.09 (0.03)	0.07 (<0.01)	262 (98)	50 (4)	58 (25)
P only	3.62 (0.59)	3.04 (0.41)	0.86 (0.08)	0.23 (0.06)	0.56 (0.10)	0.42 (0.03)	0.06 (0.01)	0.13 (0.01)	142 (54)	47 (6)	43 (5)
Lime only	3.30 (0.40)	2.90 (0.04)	0.91 (0.06)	0.18 (0.01)	0.58 (0.16)	0.50 (0.02)	0.06 (0.02)	0.07 (<0.01)	154 (69)	42 (3)	37 (13)
N+P	4.95 (0.49)	3.14 (0.32)	1.40 (0.14)	0.24 (0.04)	0.55 (0.16)	0.57 (0.11)	0.09 (0.01)	0.09 (0.03)	216 (27)	51 (9)	48 (6)
Lime + N	4.38 (0.73)	3.15 (0.50)	1.26 (0.05)	0.18 (0.01)	0.54 (0.03)	0.60 (0.03)	0.08 (0.02)	0.07 (0.02)	227 (59)	54 (7)	60 (19)
Lime + P	3.16 (0.40)	3.30 (0.20)	0.87 (0.08)	0.20 (0.03)	0.54 (0.06)	0.52 (0.08)	0.08 (0.03)	0.09 (0.01)	200 (54)	45 (14)	50 (5)
Lime + N+P	4.03 (0.58)	3.09 (0.23)	1.22 (0.11)	0.20 (0.04)	0.46 (0.14)	0.68 (0.02)	0.07 (0.04)	0.05 (0.01)	221 (58)	44 (9)	46 (13)

[a] Standard deviation in parenthesis.

Table 5.—Means and standard deviations of ash and nutrient contents for balsam fir foliage three growing seasons after treatment.

Treatment	Ash	Nutrient								
		N	P	Ca	K	Mg	Mn	Na	Fe	Zn
	mg/1000 needles									
Control	114.5 (16.9)[a]	32.4 (3.0)	6.3 (0.6)	17.7 (3.1)	20.9 (2.1)	2.9 (0.9)	5.3 (0.4)	0.58 (0.14)	0.12 (0.02)	0.17 (0.04)
N only	136.9 (38.4)	57.7 (1.6)	7.6 (0.8)	27.4 (10.7)	21.1 (9.4)	4.5 (1.9)	3.5 (0.3)	1.28 (0.61)	0.24 (0.04)	0.28 (0.15)
P only	108.4 (4.7)	31.3 (8.0)	8.1 (1.6)	20.4 (5.3)	15.3 (3.4)	2.2 (0.7)	4.5 (0.4)	0.53 (0.29)	0.17 (0.02)	0.16 (0.04)
Lime only	95.4 (10.2)	30.4 (5.6)	5.9 (0.9)	18.8 (2.9)	16.3 (1.2)	2.1 (0.8)	2.2 (0.3)	0.52 (0.29)	0.14 (0.03)	0.12 (0.06)
N+P	155.8 (22.0)	69.1 (3.0)	11.8 (3.1)	27.5 (8.0)	28.1 (6.0)	4.5 (0.5)	4.4 (1.4)	1.07 (0.22)	0.26 (0.06)	0.24 (0.05)
Lime + N	140.7 (46.8)	55.5 (11.4)	7.8 (1.5)	23.9 (4.2)	26.3 (5.8)	3.5 (0.6)	3.0 (0.9)	0.97 (0.17)	0.24 (0.07)	0.26 (0.08)
Lime + P	104.8 (19.6)	27.7 (6.3)	6.4 (1.6)	17.3 (3.9)	16.5 (4.5)	2.5 (1.4)	2.9 (0.3)	0.62 (0.10)	0.15 (0.06)	0.16 (0.04)
Lime + N+P	125.0 (26.3)	48.6 (5.8)	8.2 (1.7)	18.7 (7.2)	27.5 (3.1)	2.9 (2.0)	2.0 (0.5)	0.90 (0.35)	0.18 (0.05)	0.18 (0.08)

[a]Standard deviation in parenthesis.

The fertilizer treatments significantly affected dry weight and levels of ash, N, P, K, and Mn in both species. Levels of Ca, Fe, Zn, and Na in balsam fir foliage also differed significantly with N fertilizer. Magnesium was the only element not significantly affected by the fertilizer treatments (Table 6).

Needle weight

Nitrogen significantly increased needle dry weight for both species (Table 6). Needles from each N treatment were heavier than the comparable non-N treatment for both species. Balsam fir needles were heavier than red spruce needles and they increased more than red spruce needles did for each treatment (Fig. 1). The addition of P tended to increase balsam fir needle weight above comparable treatments without P. Lime tended to decrease needle weight below each equivalent treatment without lime.

The three-way NP lime interaction was significant for red spruce needle weight (Table 6). We interpret this to mean that both P and lime affected the way red spruce needle weight responded to N. When either P or lime was added in combination with N, needle weight significantly increased above control and N alone. But, when both P and lime were added with N, needle weight was only slightly greater than for N alone. Although the main effect of neither P nor lime was significant, each tended to have a negative effect on needle weight and thus contributed to the significant NP lime interaction (Fig. 1).

Table 6.—Summary of analysis of variance showing significant effects for foliar nutrient levels of balsam fir and red spruce in soils fertilized with N, P, and lime.

Source of variation		Dry weight	Ash	N	P	K	Ca	Mg	Fe	Mn	Zn	Na
					BALSAM FIR							
N	Concentration[a]	**		**					*	**		
	Content[b]		**	**	**	**	*		**		**	**
P	Concentration				**							
	Content				*							
Lime	Concentration									**		
	Content			*						**		
NP	Concentration					*						
	Content											
Lime + N	Concentration									*		
	Content											
Lime + NP	Concentration									*		
	Content									*		
					RED SPRUCE							
N	Concentration	**		**						*		
	Content			**								
P	Concentration				*							
	Content											
Lime	Concentration									*		
	Content									*		
NP	Concentration					*						
	Content					*						
Lime + N	Concentration											
	Content					*						
Lime + NP	Concentration	*										
	Content		*	*		*						

[a]Foliar concentration is percent or ppm
[b]Content per needle.
*significant at 5% level.
**significant at 1% level.

Ash

Ash content (μg/needle) of both species followed the response pattern of needle dry weight discussed previously. The ash content of balsam fir foliage was significantly increased by N fertilizer. The ash content of red spruce foliage was influenced primarily by N but the P and lime treatments had significantly different impacts on the response to N as indicated by the significant NP lime interaction (Table 6). Ash components varied in proportion to overall weight increases, keeping concentrations relatively constant at around 3 percent in balsam fir foliage and 2.5 percent in red spruce (Fig. 2).

Nitrogen

Nitrogen fertilizer stimulated the uptake of N in both balsam fir and red spruce foliage. The main effect of N was highly significant for both concentration and content of N in both species (Table 6). Foliage from red spruce trees treated with N averaged 1.08 percent and 20 μg per needle compared with 0.76 percent and 12 μg for foliage from trees not treated with N. The N levels for balsam fir foliage averaged 1.28 percent and 58 μg per needle for trees treated with N compared with 0.90 percent and 30 μg per needle for non-N treatments. The NP lime interaction term was significant for N content of red

Figure 1.—Effect of N, P, and lime treatments on average dry weight of red spruce and balsam fir needles.

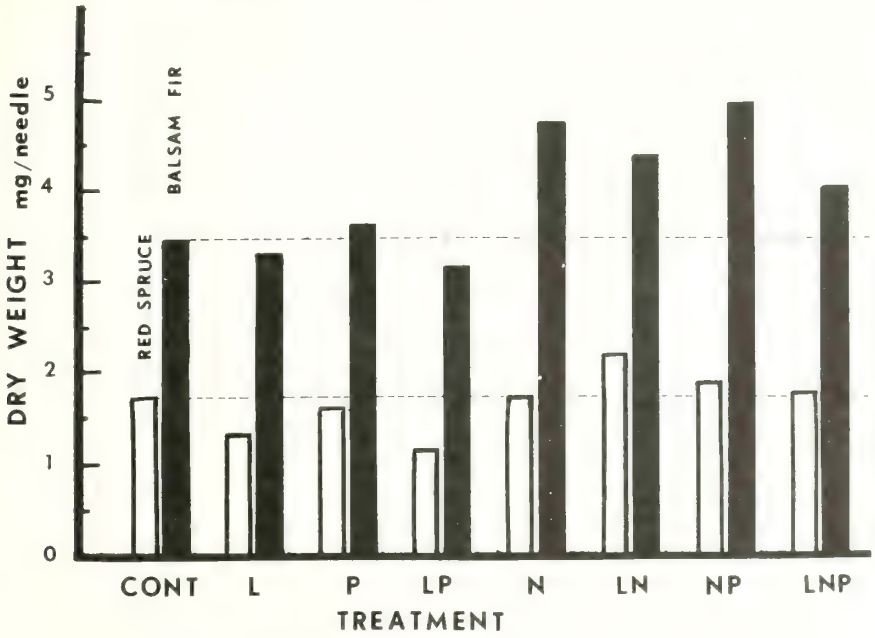


Figure 2.—Average ash levels in red spruce and balsam fir foliage from trees treated with N, P, and lime.

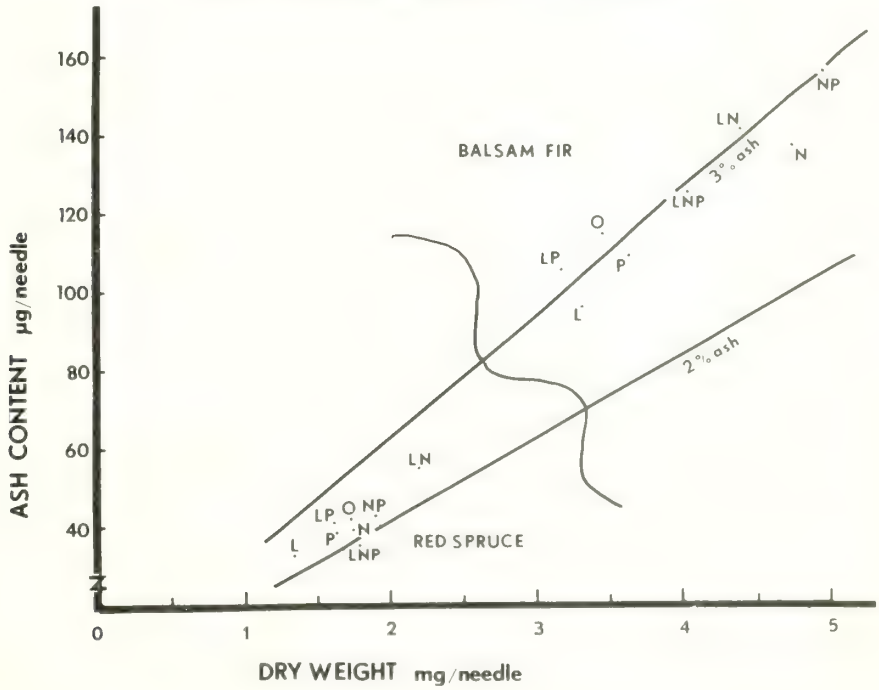
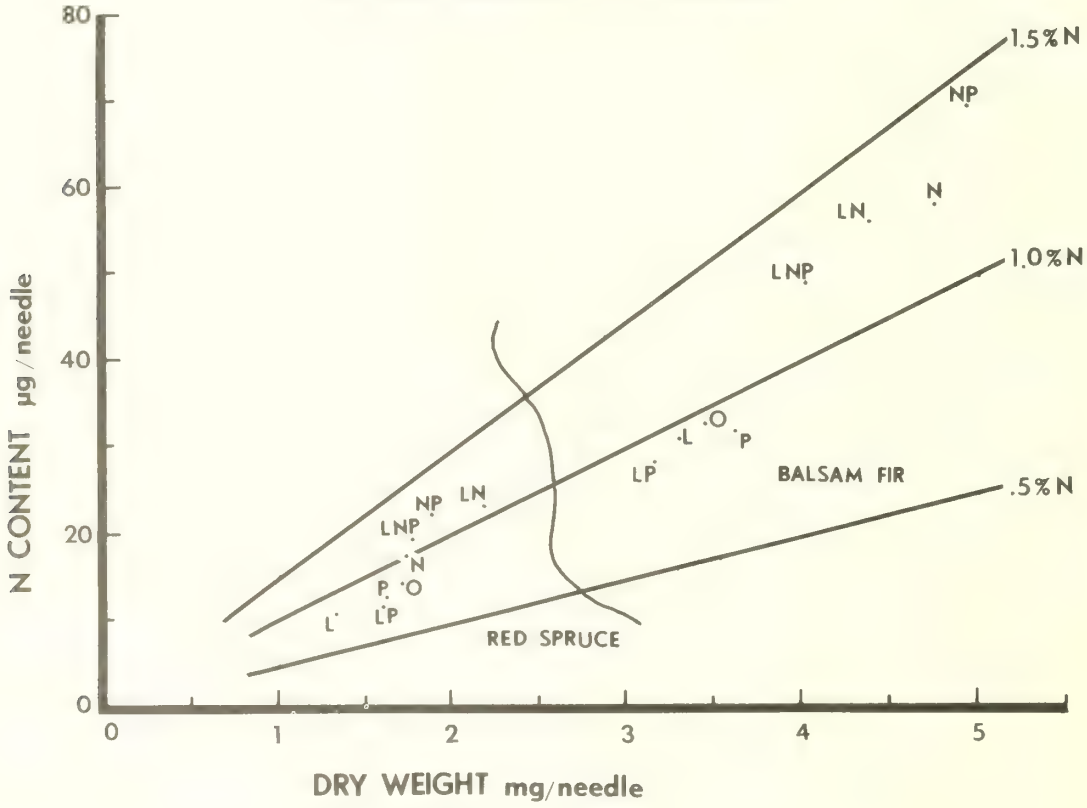


Figure 3.—Average N levels in red spruce and balsam fir foliage from trees treated with N, P, and lime.



spruce foliage. When either P or lime was added in combination with N, the N content of red spruce needles increased above that for trees treated with N alone. But when P and lime were added together with N, the N content decreased to the N only level (Fig. 3). This corresponds to the significant NP lime interaction on needle weight already discussed. We interpret this to mean that the needle components that constituted the increased dry weight contained N and that the N concentration in these components was about the same as that in the untreated needles.

Nitrogen content of balsam fir needles was significantly decreased by lime (Table 6). Foliage from balsam fir trees treated with lime ranged from 2 to 20 µg N per needle less than each treatment without lime (Fig. 3). These lower contents resulted from the trend of decreased weight per needle for lime as well as a trend of decreased concentration in some treatments (Table 4). The greatest difference was between the NP and NP lime treatments. Apparently, this difference was not so much a reduction of N uptake as it was a suppression of response to the NP fertilizer combination. That is, the NP treatment produced the heaviest needles (4.95 mg) with the greatest N content (69 µg). In the NP lime treatments, the needles were still heavier than control (4.03 versus 3.45 mg) and had a greater N content (49 versus 32 µg).

Czapowskyj, Miroslaw M., L. O. Safford, and Russell D. Briggs.
1980. **Foliar nutrient status of young red spruce and balsam fir in a fertilized stand.** Northeast For. Exp. Stn., Broomall, Pa.
16 p., illus. (USDA For. Serv. Res. Pap. NE-467).

Average dry weight and nutrient levels in current foliage from red spruce and balsam fir saplings in the understory of a 25-year-old aspen birch stand were observed 3 years after N, P, and lime treatments were applied. Elemental concentrations were plotted as a function of needle weight and quantity of element per needle. In balsam fir, needle weight and levels of ash, N, P, K, Ca, Fe, Mn, Zn, and Na differed among treatments. In red spruce, needle weight, N, P, and Fe differed among treatments. In both species there were significant interactions among the N, P, and lime treatments. Balsam fir needles were heavier, contained higher levels of most elements, and showed a greater response to treatment than red spruce needles.

237.4:160.2

Keywords: Fertilizer treatments; foliar chemistry; *Picea rubens; Abies balsamea*

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Phosphorus

Phosphorus fertilizer significantly increased concentration and content of P in balsam fir foliage and P concentration only in red spruce foliage. None of the interaction terms was significant (Table 6). All treatments with P averaged 0.22 percent and 8.6 μg per needle P in balsam fir needles compared with 0.18 percent and 7.0 μg for non-P treatments. In red spruce foliage from trees treated with P, the P concentration was 0.17 percent and that of non-P treatments was 0.15 percent (Fig. 4).

Potassium

The K content of balsam fir foliage was significantly affected by N, and the K concentration was significantly affected by the NP interaction term (Table 6). In red spruce foliage, the NP interaction term was significant for both K concentration and content. The K content was also significantly affected by the N lime and NP lime interaction (Table 6).

In foliage of balsam fir trees treated with N, the content of K averaged 25.7 μg per needle whereas needles from trees not treated with N contained 17.3 μg of K. This difference resulted from the increase in dry weight per needle caused by the N treatments in combination with a tendency for N-treated trees to have higher concentrations of K, 0.58 percent compared with non-N treatments, 0.51 percent. We interpret the significant NP interaction term as follows:

Figure 4.—Average P levels in red spruce and balsam fir foliage from trees treated with N, P, and lime.

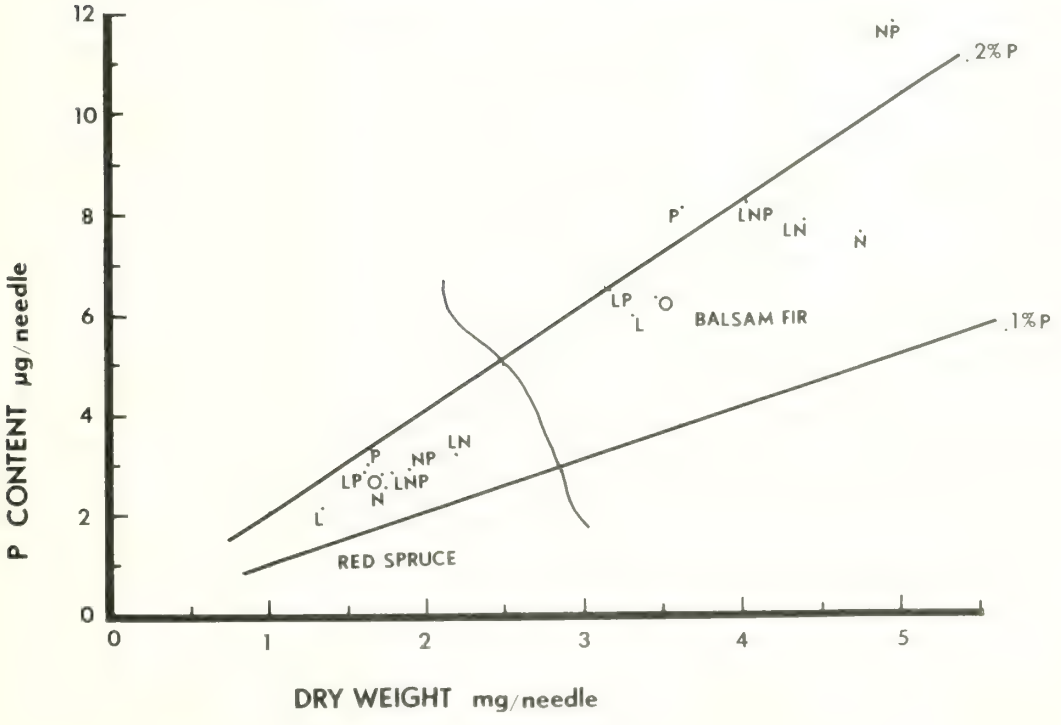
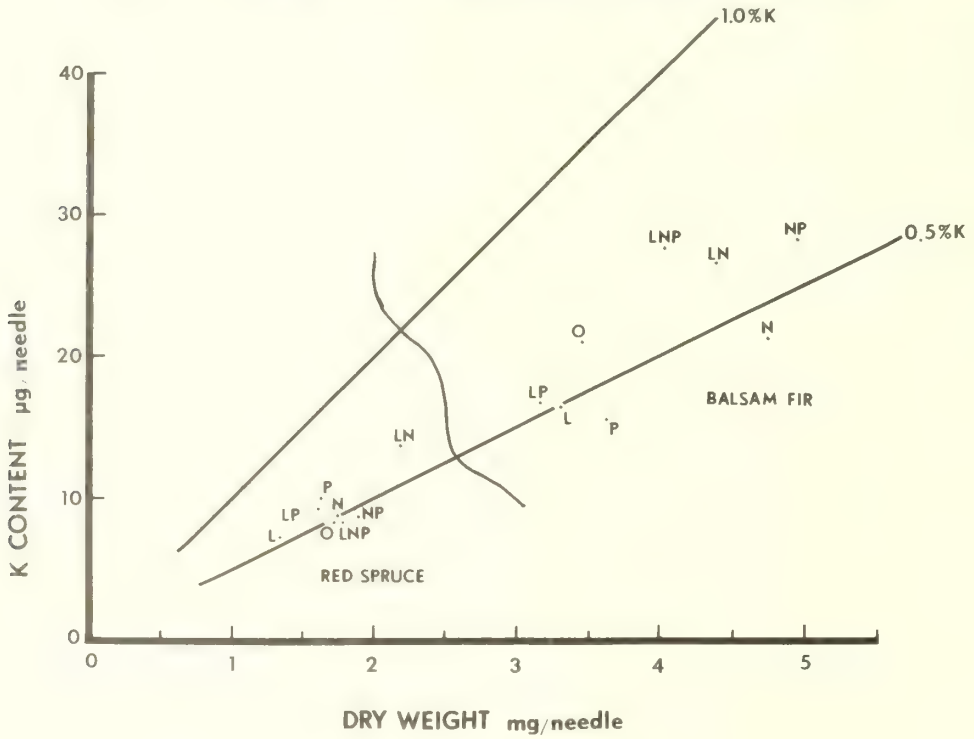


Figure 5.—Average K levels in red spruce and balsam fir foliage from trees treated with N, P, and lime.



In the absence of N, the foliage of balsam fir treated with P contained 0.47 percent K, but in the presence of N, the concentration of K was increased to 0.62 percent by the addition of P (Fig. 5).

The K content of red spruce needles was significantly affected by the NP, N lime, and NP lime interaction terms. Concentration of K in the foliage was significantly affected only by the NP interaction (Table 6). The effect of the NP interaction on red spruce foliar K was the reverse of that on balsam fir. Potassium concentration was increased by P in the absence of N to 0.58 percent and depressed in the presence of N to 0.45 percent (Fig. 5).

It is difficult to interpret the simultaneous significance of these interaction terms—NP, N lime, and NP lime—on K content of red spruce foliage. Lime by itself depressed K content below control (7.0 vs. 8.2 µg/needle). However, lime substantially increased K content in combination with N (13.5 vs. 8.7 µg/needle). The effect of NP interaction on K content was the same as on K concentration already discussed. The NP lime interaction can be interpreted as paralleling the significant interaction on needle dry weight already discussed.

Calcium

The Ca content of balsam fir needles was significantly increased by N fertilizer (Table 6), averaging 24 μg per needle versus 18 μg per needle for non-N treatments. This increase results from the increased needle weight from N treatments (Fig. 6). No other treatments or interactions were significant for Ca in balsam fir or red spruce foliage.

Calcium concentration in balsam fir foliage (0.54 percent) was about double that of red spruce foliage (0.29 percent). This could indicate that either the fir has a higher Ca requirement or a greater ability to extract Ca from the soil than red spruce (Fig. 6).

Iron

The iron concentration and content of balsam fir foliage were both significantly increased by N treatments (Table 6). Foliage from balsam fir trees treated with N averaged 50 ppm and 23 μg per needle versus 43 ppm and 14 μg per needle for treatments without N. There was a trend for each of the lime and fertilizer treatments to increase Fe levels in balsam fir foliage (Fig. 7). Red spruce foliar Fe was unaffected.

Manganese

The concentration of Mn in balsam fir foliage responded significantly to N, lime, and N lime and NP lime interactions; Mn content was significantly affected by lime and the NP lime interaction. In red spruce foliage, Mn concentration was significantly changed by N and lime, and the Mn content by lime only (Table 6).

All fertilizer treatments tended to decrease

Figure 6.—Average Ca levels in red spruce and balsam fir foliage from trees treated with N, P, and lime.

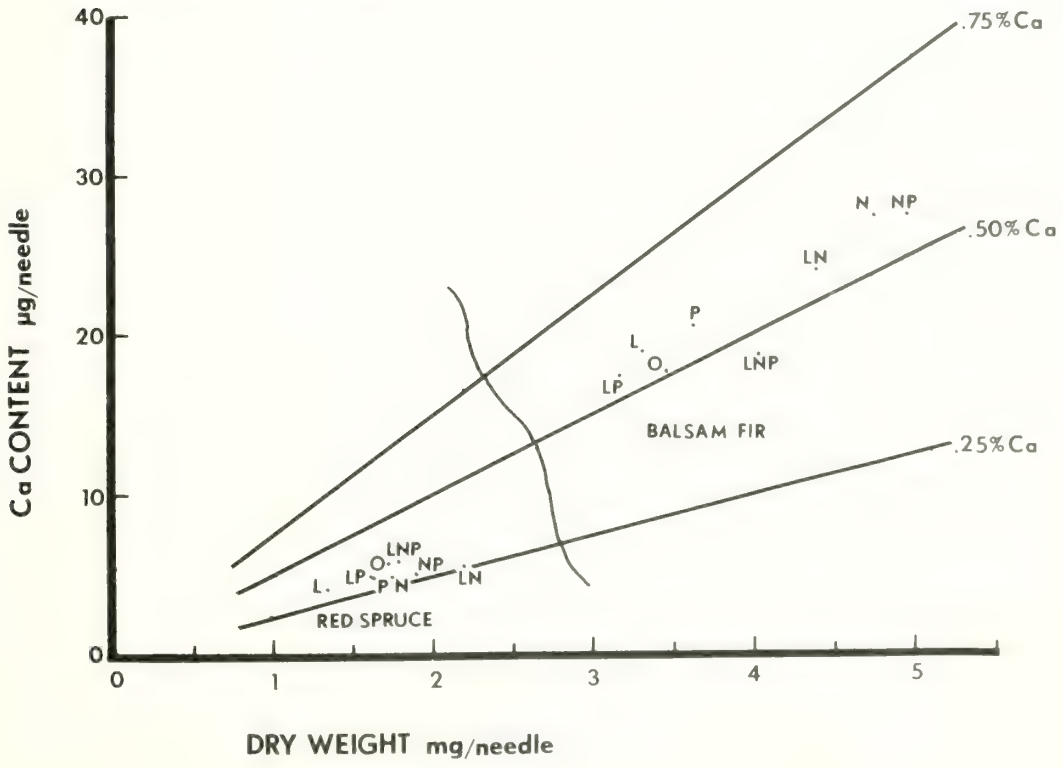
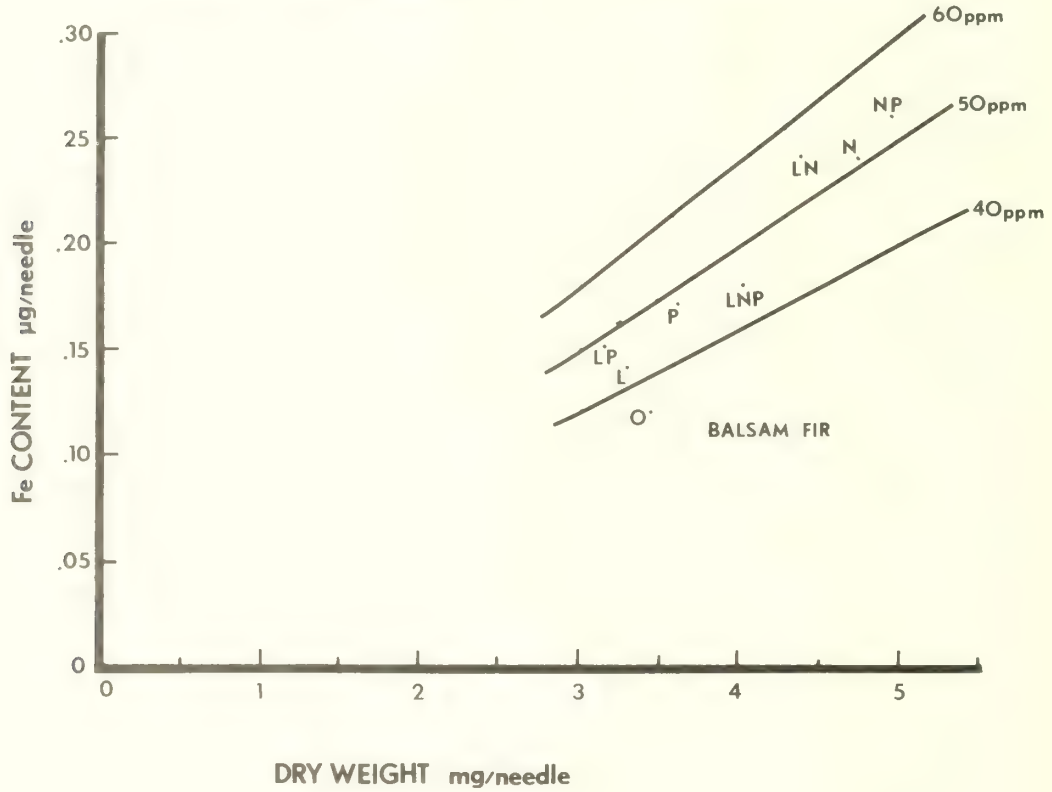


Figure 7.—Average Fe levels in balsam fir foliage from trees treated with N, P, and lime.



Mn levels—both concentration and content—in the foliage of both species (Fig. 8). In balsam fir foliage, treatments that included N averaged 0.07 percent Mn; those without N averaged 0.11 percent Mn. This is a dilution effect created by the gain in needle weight in response to N fertilizer. Lime decreased both average concentration and content of Mn from 0.11 percent and 4.4 µg per needle to 0.07 percent and 2.6 µg per needle. These decreases resulted from reduced uptake of Mn of balsam fir trees from plots treated with lime. The significant N lime interaction resulted from a greater reduction of Mn concentration by N in the absence of lime—0.14 to 0.08 percent—than in the presence of lime—0.08 to 0.06 percent. The significant NP lime interaction resulted from an increase or no change in Mn levels when N or P was combined with lime only; whereas, NP plus lime resulted in the greatest reduction of Mn of all treatments (Fig. 8).

In red spruce foliage from trees treated with N, concentration of Mn averaged 0.09 percent versus 0.18 percent for non-N treatments. This decrease is partially a dilution effect and partly decreased uptake in the NP and NP lime treatments (Fig. 8); Mn concentration in foliage from red spruce trees treated with lime decreased from 0.13 percent to 0.08 percent, and Mn content decreased from 2.2 to 1.5 µg per needle. This decline results primarily from decreased uptake of Mn (Fig. 8).

Zinc

The Zn content of balsam fir foliage was significantly increased by N fertilizer. None of the treatments significantly affected the Zn levels in red spruce foliage (Table 6). The Zn content of balsam fir foliage averaged 0.24 μg per needle compared with 0.15 μg for non-N treatments. This significant increase in Zn content reflects the increase in total needle weight caused by N treatment and a trend toward greater Zn uptake in the N and N lime treatments (Fig. 9).

Sodium

The Na content of balsam fir foliage was significantly increased by N fertilizer. None of the treatments affected Na levels in red spruce foliage (Table 6). The Na content averaged 1.06 μg per needle for treatments with N compared with 0.56 μg per needle for non-N treatments. This significant increase in Na level reflects the increase in total needle weight caused by N treatments plus a trend of greater uptake of Na in the N treatments, which averaged 231 ppm Na versus 169 ppm for the non-N treatments (Fig. 10).

Figure 8.—Average Mn levels in red spruce and balsam fir foliage from trees treated with N, P, and lime.

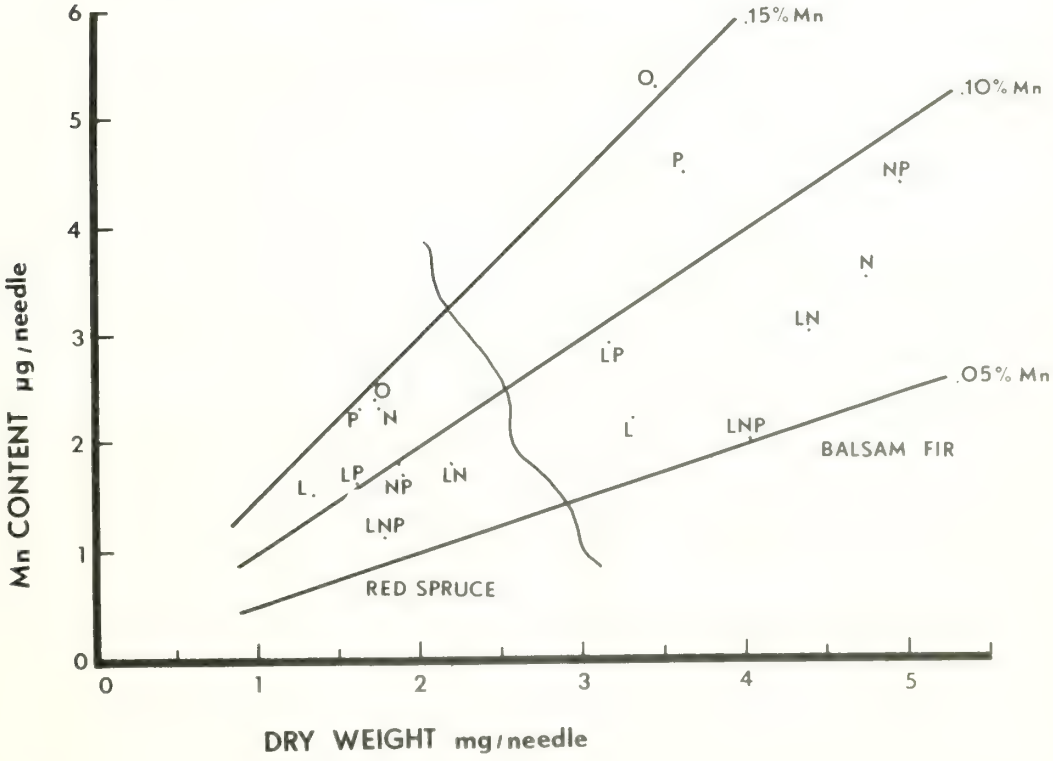


Figure 9.—Average Zn levels in balsam fir foliage from trees treated with N, P, and lime.

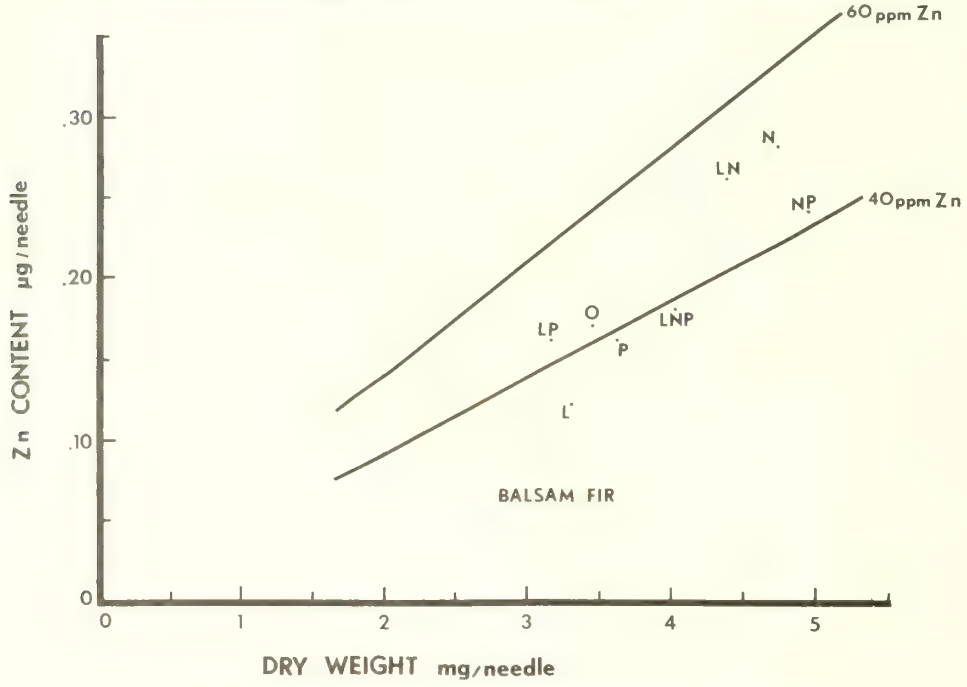
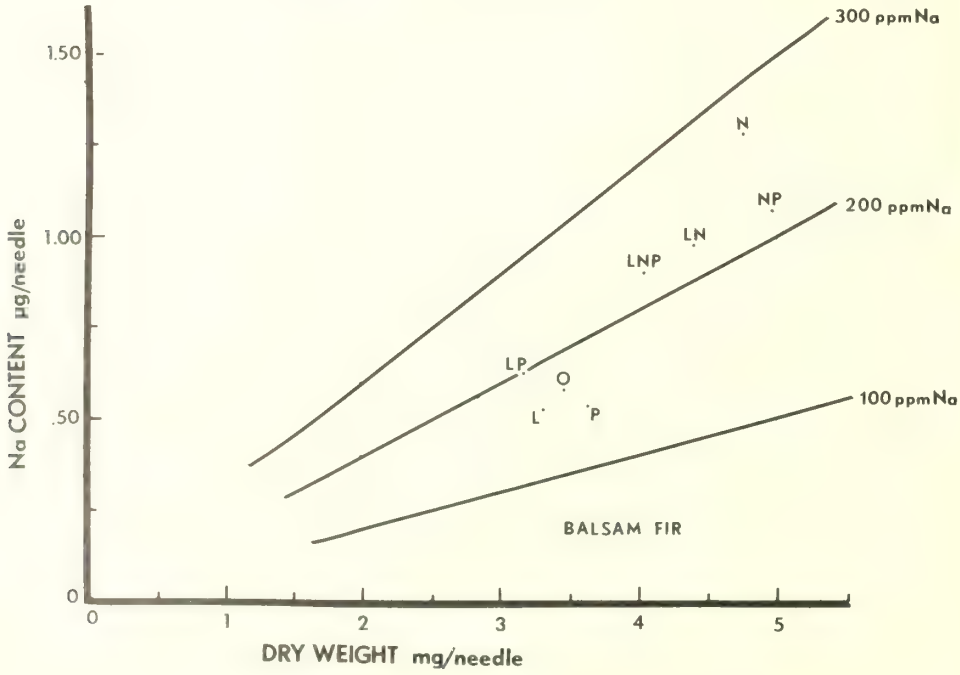


Figure 10.—Average Na levels in balsam fir foliage from trees treated with N, P, and lime.



by Edward L. Fisher
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Abstract

Logging systems that are profitable and environmentally acceptable are needed in Appalachian hardwood forests. Small, mobile cable yarders show promise in meeting both economic and environmental objectives. One such yarder, the Ecologger, was tested on the Jefferson National Forest near Marion, Virginia. Production rates and costs are presented for the system along with a discussion of the complete operation.

INTRODUCTION

PROFITABLE AND ENVIRONMENTALLY acceptable logging systems are needed in Appalachian forests. These systems should be able to thin even-aged stands, remove individual trees from uneven-aged stands, and harvest mature trees. A critical phase of the logging operation is transporting logs from the stump to the landing. This phase accounts for a large portion of the total harvesting cost—usually at least 30 percent—and can result in serious damage to the environment. The articulated skidders and crawlers currently used in Appalachia often damage residual trees and require a network of logging roads, which are unsightly and a major source of soil disturbance on steep sites.

One objective of forest management is developing a logging system that not only operates economically in Appalachian hardwood stands but also has a less detrimental impact on the environment (primarily by reducing the number of haul and skidroads) than conventional tractor systems. Cable logging shows promise in meeting this objective.

Of the cable systems available, we believe the lighter, less costly systems would be effective in Appalachia (Gibson and Phillips 1973) because:

1. Slopes are predominantly convex in Appalachia. In West Virginia and the steeper areas of Pennsylvania, 95 percent of the slopes fit this category. This is true for much of Appalachia. Smaller cable systems with a reach of 1,000 feet or less would minimize the problems associated with convex slopes.

2. Private individuals own most of the forest land and their tracts are of limited size—80 percent of the growing stock in West Virginia, typical of Appalachia in this regard, is owned by private individuals. Small cable systems are highly mobile and can easily be moved into small tracts. These machines also can be moved on state highways without violating vehicle standards on height, width, and weight.

3. The small cable systems have a lower initial cost than large cable systems and thus can be better matched to small timber.

4. Small cable systems do not require wide roads; this means more land available for tree production and lower road construction costs in steep areas where these costs are highest. Also, narrow roads are not highly visible and pose a less serious threat of erosion because less soil is disturbed.

In this study we used a small, mobile cable system to harvest timber on steep Appalachian slopes. We then determined production rates, costs, and generally assessed damage to the environment.

TEST AREA

The site chosen for harvest was a 62-acre tract located within the Jefferson National Forest near Marion, Virginia. The sale was planned by the National Forest under the jurisdiction of the Mount Rogers National Recreational Area. A private contractor did the logging; logs were trucked 52 miles to a sawmill in Clinchburg, Virginia. The prescription for all harvesting was clearcutting. Timber harvested was primarily basswood, black and yellow birch, red and white oak, and sugar maple. There were smaller amounts of ash, hard maple, and cherry. The average diameter (average of small and large ends) of the harvested logs was 15 inches with a minimum top diameter of 8 inches. The average slope was 56 percent and the maximum yarding distance was 700 feet.

LOGGING SYSTEM

Equipment and manpower

The equipment used in the operation was an Ecologger[1] live skyline yarder (Figs. 1, 2), mounted on a 130-horsepower Tree Farmer C6D skidder. The system was equipped with a hydraulically operated yarding tower, guylines, mainline, and skyline. A Maki carriage was used to bring the logs to the landing. Specifications are given in the Appendix. The cost of the yarder including the skidder was approximately $130,000 at the time of the operation. This yarder, minus the skidder, can now be purchased for about $65,000. Other equipment included a small bulldozer, a Prentice 200 loader/mechanical bucker, and two log trucks. The crew consisted of two chokersetters, one operator/chaser, one foreman, two fellers, supervisory personnel (fractional time) and two swing men responsible for bucking at the landing, loading, operating a bulldozer in the construction of additional landings, and hauling logs to the mill. The yarder was equipped with remote electronic controls to enable the operator to unhook logs at the landing. This innovation allowed yarding to be done by a three-man crew.

Description of operation

After felling, the yarder was set up by four men in about 4 hours. This operation included disassembling the set just finished, moving the machine to the next set, leveling it, extending four guy wires and securing them, rigging the skyline to the first tail tree of the set, and setting the carriage stop at the first position.

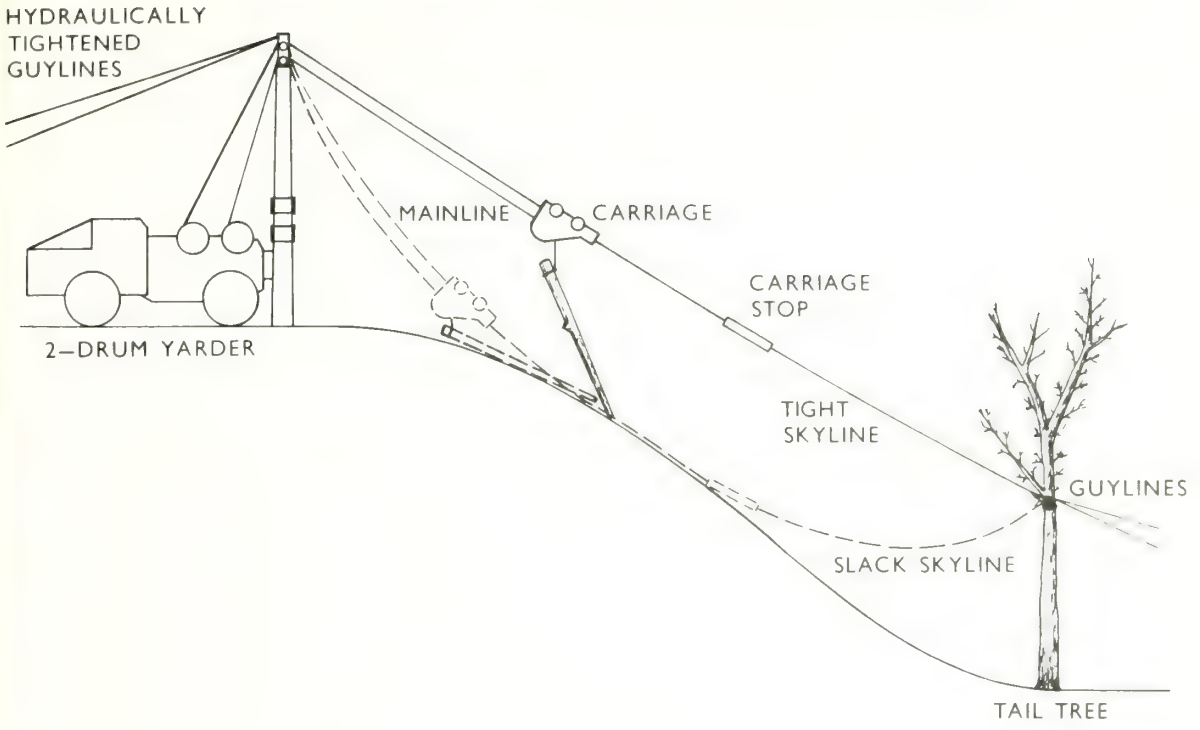
After the set-up had been completed, the skyline was tensioned and the carriage allowed to travel empty to the line stop. When the carriage hit the stop, the skyline was slackened and the end of the mainline was attached to one or two sawlogs, depending on the weight and location of the logs. The skyline is termed "live" because of this ability to be slackened.

Generally, logs were yarded tree length. When a signal was given, the skyline was retensioned and the logs were winched laterally to the skyline corridor. When the logs reached the carriage, the carriage was automatically released from the stop, allowing the payload to be pulled uphill to the landing. When the logs reached the landing, the skyline was

Figure 1.—The Ecologger live skyline yarder wa mounted on a 130-horsepower Tree Farmer C6 skidder.

[1] The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

Figure 2.—Schematic of live skyline cable yarding system.



slackened to allow unhooking. Yarding was done in a fan-shaped swath with several paths per set. Usually, each path was yarded top to bottom before the skyline was moved to the next tailhold.

Timing the operation

The snapback timing method of work sampling was used to break down the total productive time into its various components. Most of the sampling was devoted to timing the yarding elements so that regression equations could be developed for each of the five phases of a complete yarding cycle, or turn: (1) travel empty, the time required to move the empty carriage from the landing to the point of loading; (2) hook, the time required to hook a turn of logs to the mainline; (3) winch lateral, the time it takes to winch logs from the hook position into the carriage; (4) travel loaded, the time required to yard the logs to the landing; and (5) unhook, the time required to unhook the logs.

The turns were timed so that no time was lost as each phase ended and a new one began. The times were recorded in minutes; delays within any phase also were timed and recorded by type.

Delays

In addition to normal delays such as log hangups, there were several major delays. During the test, lightning struck the tower, causing a malfunction of the electronic controls and delaying the operation. Other major delays resulted from a lack of local replacement parts and the absence of a skidder (and frequently a loader) on the landing to remove logs from the deck in front of the yarder. Decking of the logs by the yarder was difficult and slow when the deck became too large. Another factor that slowed the logging operation was the inexperience of the crew. In other cable logging tests, we have found that it can take months of training and experience before workers become proficient in rigging procedures (Gochenour et al. 1979). These problems should be reduced or elimi-

nated before additional field trials are attempted.

RESULTS

Productivity

The men worked four 10-hour days per week. Average production time per cycle was 7.13 minutes. With delays, the average cycle time was 9.20 minutes. The average volume per turn was 52.8 cubic feet with an average log diameter of 15 inches and length of 34 feet. The average number of logs per turn was 1.35, and the average slope yarding distance was 369 feet.

The major delays within a cycle were: 1) moving the carriage stop (8.75 minutes per move) and 2) repairing the cable (21.5 minutes per repair). The time needed to move the stop was longer than expected because large amounts of ground slash made maneuvering difficult. Road changing required an average of 67.2 minutes and ranged from 37 to 97 minutes (Table 1).

Table 1.—Average time and standard deviation of phases and delays in yarding cycle, in minutes[a/]

Item	Average time	SD
Travel empty	0.55	0.29
Hook	3.11	1.48
Winch laterally	0.56	0.60
Travel loaded	1.02	0.94
Unhook	1.75	0.85
Cycle without delay	7.13	2.28
Cycle with delay	9.20	7.04
Delay per cycle	2.07	7.52
Time per delay	12.38	12.78

[a]Based on 95 cycles.

The average time needed to change landings was approximately 4 hours. Results of multiple regression analysis of cycle times are given in Table 2. Variables that were significant at or below the 5-percent level were used in the equations. These included yarding distance (lateral and slope) and the number of stems per turn.

Table 2.—Results of regression analysis of phases of yarding cycle (estimate of time in minutes)[a/]

Yarding phase	Equation	R^2	SE
Travel empty	Y = .198 + .00081662(X1)[b]	0.36	.12
Hook	Y = .776 + .00346128(X1) + .01158483(X2)[c] + .32828497(X3)[d]	0.24	.89
Winch Laterally	Y = .038 + .00105710(X1) + .00250582(X2)	0.16	.30
Travel loaded	Y = .111 + .00215421(X1)	0.44	.28
Unhook	Y = .552 + .00148312(X1) + .36986199(X3)	0.22	.57
Total cycle	Y = 2.374 + .00841141(X1) + .72548570(X3)	0.40	1.30

[a]All coefficients significant at 5 percent level.
[b]X1 = slope yarding distance (ft).
[c]X2 = lateral yarding distance (ft).
[d]X3 = number of stems per turn.

DISCUSSION

Three years after treatment, weight of current-year needles, both balsam fir and red spruce, increased in response to nitrogen fertilizer. This fact implicates nitrogen as being a growth limiting nutrient on the site.

Foliar nutrient levels in balsam fir needles appear to have responded more to fertilization than those of red spruce. Every foliar nutrient (except Mg) changed significantly in response to N fertilization. In red spruce, N was the only element that increased significantly in response to N fertilizer. Also, needle mean dry weight for balsam fir increased by 34 percent compared with a 21 percent increase for red spruce in response to N fertilization.

Although not greatly different, average concentrations of ash and each element except Fe, Mn, and Na were higher in balsam fir than in red spruce. And, because of the greater weight per needle, the content of every element was greater in balsam fir. The substantially higher concentration (0.54 vs. 0.25 percent) and content (18 vs. 6 μg per needle) of Ca in balsam fir may indicate a fundamental difference in Ca requirements or in capacity of the two species to absorb and translocate Ca. The addition of lime had no direct effect on either Ca or Mg levels in either species. Apparently, the surface application of ground limestone was less available to the understory stand than to the overstory hardwoods, which increased uptake of both Ca and Mg (Czapowskyj and Safford 1979; Schmitt et al. 1979). Another possibility for this lack of response is that the conifer's requirements may have been satisfied by the quantities of Ca and Mg available in the untreated soil.

Nutrient concentration is a function of needle dry weight and nutrient content. Therefore, significant changes in nutrient concentration reflect changes in dry weight or nutrient content, or both. When significant increases in nutrient content are not accompanied by a significant increase in concentration, the logical hypothesis is that increases in dry weight are responsible for the observed increases in nutrient content. In the case of balsam fir, contents of ash, Ca, K, Fe, Zn, and Na contributed to increased needle weight. That is, the content of these elements increased at a rate in proportion to the dry weight increase of the needles. The contents of N, P, and Fe increased at a greater rate than dry weight; therefore, concentrations of N, P, and Fe were higher. But the content of Mn diminished even though dry weight was greater; there was a reduction of Mn concentration. These relationships are easily observed in Figures 2-10, where elemental content is plotted as a function of needle weight by the concept described by Safford (1978) as an alternative to that suggested by Timmer and Stone (1978) based on earlier references. The use of this method allows a new interpretation of the response to each of the treatments.

CONCLUSIONS

On the basis of the results of this study, we draw the following conclusions about the response of understory red spruce and balsam fir to fertilizer and lime treatments.

1. Dry weight and levels of ash, N, P, K, Ca, Fe, Mn, Zn, and Na were significantly affected by fertilizer treatments, especially by N alone and in combination with P and lime. The significance of several interaction terms indicated that response to a given element or elements may depend on the status of other elements.
2. Balsam fir needles were heavier and had generally higher levels of nutrient elements than red spruce needles, especially Ca concentration and content.
3. Balsam fir foliage exhibited a greater response to fertilizer treatments, both in the number of elements significantly changed and in the magnitude of the changes.

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Headquarters of the Northeastern Forest Experiment Station are in Broomall, Pa. Field laboratories and research units are maintained at:

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HARDWOOD LOG GRADES
and Lumber Grade Yields for Factory Lumber Logs

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Abstract

The USDA Forest Service Standard Grades for Hardwood Factory Lumber Logs are described, and lumber grade yields for 16 species and 2 species groups are presented by log grade and log diameter. The grades enable foresters, log buyers, and log sellers to select and grade those logs suitable for conversion into standard factory grade lumber. By using the appropriate lumber grade yields, log buyers and sellers can appraise the logs in terms of expected lumber grade volume and value. This report supersedes an earlier report on hardwood log grading, Forest Service Research Paper FPL 63.

INTRODUCTION

SAWMILL OPERATORS learned long ago that small, knotty logs are less valuable than large, clear ones. Hardwood sawlog grading systems were first developed in the early 1900's to assist buyers and sellers when logs were being appraised. Through the years, the supply of high-quality timber has decreased while demand and price have increased. Thus, the significance of evaluating quality during the production, harvesting, and processing of sawlogs has never been more important. Log grades are a tool that can help maximize the potential yield of high-value products from the timber resource.

BACKGROUND

The hardwood log grade specifications presented here were originally published in 1949 by the USDA Forest Service's Forest Products Laboratory. This system enables foresters, timber sellers, and timber buyers to separate, from woods-run hardwood logs, those logs that are suitable for manufacture into factory grade lumber, and to rank the logs into categories of high-, medium-, and low-quality yields. In 1952 the grades were adopted as the official hardwood log grades for use by the Forest Service. Lumber grade yields accompanied the earlier report that was revised in 1966 (Vaughan et al. 1966). The yields are tabulated by species, log grade, and diameter class and represent the percentage of total lumber tally for each class that was assigned to the National Hardwood Lumber Association's (NHLA) lumber grades. Additional information on lumber grade yield has been collected in recent years and is combined with the previously reported yields. Yields for 16 individual species and two groups of lowland oak species are presented. These yields, when coupled with lumber prices, provide a means for estimating the value of lumber that can be sawed from graded logs.

LOG GRADE SPECIFICATIONS

A log grading system can be defined as a set of specifications that is used to segregate a given lot of cut logs into two or more log grades.[1] To that definition has been added the requirement that there be significant differences in unit value or in end product yield between the log grades.

During the development of the hardwood log grade specifications, many of the variables studied were discarded because they were not reliable in segregating logs into distinct groups. The following are the variables that were included in the specifications.

Log diameter

Log diameter inside bark (dib) at the small end is the single most important variable related to lumber grade yield and log value. The lumber grade yields in this paper are tabulated by log grade and scaling diameter so that diameter functions as a continuous grading factor within the log grades.

Large logs are more valuable than small logs because they contain more lumber, and the lumber often is worth more per board foot. Large logs typically contain more defect-free wood than small logs, so more high-grade lumber is produced. This is a result of natural pruning followed by clear wood being laid down over the central core of knots. Large logs also result in the production of wider boards; and as board width increases, lumber grade also increases.

Log length

Log length is a grading factor for grade 1 logs. A minimum length of 10 feet is imposed, whereas grade 2 and 3 logs may be as short as 8 feet. Loggers who sell graded logs should buck high-quality logs into

[1] Newport, Carl A., C.R. Lockard, and C.L. Vaughn. 1958. Log and tree grading as a means of measuring quality. USDA Forest Service report of the National Log Grade committee. 31 p.

lengths of 10 feet or more. The 10-foot minimum length for grade 1 logs relates to length specifications found in the NHLA rules for grading hardwood lumber. The NHLA rules limit the proportion of short lumber permitted in a shipment of the better grades.

Log position

Whether a log is a butt or an upper log is a grading factor for grade 1 logs. Both types of logs are permitted in grade 1. However, butt logs may be as small as 13 inches dib, whereas upper logs must scale at least 16 inches dib.

Clear cuttings

As part of the grading procedure, the log's surface is visually divided into four equal faces. High-quality sawlogs are characterized by faces with long, defect-free areas called clear cuttings. Sawlogs of low quality have shorter clear cuttings. The rules related to clear cuttings (Fig. 1) were derived from NHLA rules for grading lumber, and the similarity is obvious when comparisons are made. The number and length of clear cuttings and the proportion of a board that is clear are considered when grading a board. The faces of a log are graded much like a board, so these same items are considered for each face.

Figure 1.—Forest Service Standard Grades for Hardwood Factory Lumber Logs.[a]

Grading factors		Log grades							
		F1			F2				F3
Position in tree		Butts only	Butts & uppers		Butts & uppers				Butts & uppers
Scaling diameter, inches		13-15[b]	16-19	20+	11+[c]		12+		8+
Length without trim, feet		10+			10+	8-9	10-11	12+	8+
Required clear cuttings[d] on each of 3 best faces[e]	Min. length, feet	7	5	3	3	3	3	3	2
	Max. number	2	2	2	2	2	2	3	No limit
	Min. proportion of log length required in clear cutting	5/6	5/6	5/6	2/3	3/4	2/3	2/3	1/2
Maximum sweep & crook allowance	For logs with less than ¼ of end in sound defects	15%			30%				50%
	For logs with more than ¼ of end in sound defects	10%			20%				35%
Maximum scaling deduction		40%[f]			50%[g]				50%
End defect:		See special instructions (page 18)							

[a] From Rast et al. 1979, revised.
[b] Ash and basswood butts can be 12 inches if they otherwise meet requirements for small #1's.
[c] Ten-inch logs of all species can be #2 if they otherwise meet requirements for small #1's.
[d] A clear cutting is a portion of a face, extending the width of the face, that is free of defects.
[e] A face is ¼ of the surface of the log as divided lengthwise.
[f] Otherwise #1 logs with 41-60% deductions can be #2.
[g] Otherwise #2 logs with 51-60% deductions can be #3.

Some of the defects that limit clear cuttings include limbs, overgrown knots, bumps, holes, and bird pecks. These are discussed in detail in "A Guide to Hardwood Log Grading" (Rast et al. 1979). Seams that extend from the surface to a depth less than one-fifth the diameter of the log at that point are not considered defects.

Sweep and crook

The volume lost due to sweep and crook is estimated when scaling a sawlog. Excess curvature results in a decrease of both lumber volume and lumber grade yield. See Rast et al. (1979) for a discussion of how to estimate percent deduction due to sweep and crook. Because sweep and crook affect lumber grade yield as well as lumber volume, the estimated percent deduction is a grading factor.

Scalable defect

Scalable defects include rot and shake as well as sweep and crook. The total deduction is limited in low-quality logs because minimum requirements must be present for a log to qualify as a factory lumber log. The amount of scalable defect is limited in high-quality logs because the overall quality of lumber is reduced in logs with large proportions of these defects.

Sound end defect

Sound end defects include gum spots, bird pecks, bark pockets, and stain. For a complete discussion of these defects, see Rast et al. (1979) and Lockard et al. (1963). The overall frequency of these defects is low, but isolated occurrences may be intense, resulting in significant damage to the potentially high-grade lumber. It is necessary to be alert for such defects because their oversight may be critical.

PROCEDURE

Data used in this study were collected over a period of 40 years. Much of the original work was carried out under the direction of the Forest Products Laboratory. In recent years, the work has been under the direction of the Northeastern Forest Experiment Station. However, the procedures have remained consistent through the years.

Log selection, diagraming, and scaling

During the first 20 years of the study, the logs were selected at mill yards. Since 1959, it has been possible to reference the log to the tree. Each log's surface and end characteristics were diagramed to provide a photolike description of the type and size of all abnormalities that could be identified.

Each log was scaled using both the International 1/4-inch and Scribner Decimal C log rules.

Sawing and lumber grading

The nearly 20,000 logs were sawed at more than 75 sawmills throughout the Eastern United States. As each log was sawed, the resulting boards were numbered so that all lumber could be referenced to the log from which it was sawed.

Each board was graded shortly after sawing, and a tally was maintained that included log number, board thickness, surface measure, and grade. For logs sawed since 1959, all boards were regraded and measured after air drying.

Log grading and log yields

The log diagrams were graded by specifications of the Forest Service Standard Grades for Hardwood Factory Lumber Logs (Fig. 1).

The lumber tally data were processed by log so that total lumber tally could be partitioned by lumber grade and thickness class. Much of the green yield data collected before 1959 were converted to dry yields by conversion factors developed by Gammon (1971).

Lumber grade yields

For each species and log grade, we determined the percentage lumber grade yields by diameter class. Lumber grade yields for the following 12 species represent dry yields (Tables 1—36). Species included are:

basswood	black oak
paper birch	chestnut oak
yellow birch	northern red oak
black cherry	scarlet oak
red maple	white oak
sugar maple	yellow-poplar

Green yields are presented for beech, cottonwood, elm, sap gum, lowland white oak, and lowland red oak (Tables 37—54). Green to air-dry conversion factors were not available for these species.

The yields for all diameters are shown in the bottom row of each yield table. These averages should not be used for a specific group of graded logs unless the diameter distribution of the group closely matches that of the logs from the table.

To better use the lumber sawed from chestnut oak logs, the boards are often graded and sold under specifications combining the term "worm holes no defect" (WHND) with the names of standard grades such as Firsts and Seconds. We followed this procedure. If you wish to estimate the yields of lumber graded by the standard lumber grades, we suggest the following conversion from tabular grades to standard grades:

Tabular Lumber Grade	*Standard Lumber Grade*
FAS — WHND	1C
F1F — WHND	2C
SEL — WHND	2C
1C — WHND	2C

The lumber thickness distributions by species and log grade are presented along with the yield tables. Use of the thickness distributions when determining log value is discussed below.

Overruns

Overrun is the percentage difference between net log scale and lumber tally. Overrun values for both the International 1/4-inch and Scribner Decimal C log rules accompany the lumber grade yields (Tables 1—54).

APPLICATION OF THE GRADES AND YIELDS

The factors considered in log grading discussed earlier include log size, position, surface defects, straightness, and soundness. When grading logs, you should develop a system that includes these factors. We suggest the following:

- Measure scaling diameter to the nearest inch.
- Measure log length to the last whole foot.
- Determine whether the log is a butt or an upper log.
- Establish the location of all defect indicators—"stoppers"—on the log's surface and ends.
- Locate the clear cuttings and the grading face.
- Measure sweep and crook and estimate scalable defect.
- Determine the log's grade.

Because a log's grade is equal to the grade of the third best face, it is often advantageous to position the faces so that one face is of lower grade than the others.

The technique of log grading cannot be perfected without actual field instruction and practice. Visits to local sawmills and logging jobs will prove invaluable in becoming acquainted with surface and end defects and how they affect lumber grade. Instruction in log grading is offered by the USDA Forest Service, State and Private Forestry, and by many states and forestry schools. If you are interested in learning how to grade hardwood logs, we encourage you to contact one of these agencies.

Bucking

Proper bucking will provide better lumber grade yields than poor bucking practices. If a sawmill operator purchases graded logs, log buckers will benefit by understanding and applying the grading rules. The same is true where the loggers are employed by the

sawmill. A complete discussion of bucking for grade is included in Petro (1971).

Allocation

The initial allocation of woods-run logs into the various log classes—veneer, construction, local use, pulp, and factory lumber—should be the decision of the bucker. As you have learned, factory lumber logs are divided into log grades 1, 2, and 3. Depending on markets and costs, an operator may choose to saw only certain grade 3 logs; or to sort out the veneer class logs from the grade 1 and 2 logs; or to process grade 1 and 2 logs at a mill different from that used to process grade 3 logs.

Timber cruising

The hardwood log grades have sometimes been applied to logs in standing trees. Problems often are encountered when estimating bucking points, inside-bark diameters, interior cull, and length of clear cuttings. These difficulties are compounded as graders attempt to grade the upper logs.

An alternative to grading logs in standing trees is available. In "Hardwood Tree Grades For Factory Lumber," Hanks (1976) described a system of tree grades requiring the grader to consider only the butt log. The butt log is graded by nearly the same specifications described in this paper, and this grade becomes the tree's grade. Included are yields for 11 species: yellow birch, paper birch, red maple, sugar maple, yellow-poplar, black cherry, basswood, northern red oak, black oak, scarlet oak, white oak, and chestnut oak. Yields for graded aspen trees are presented in "Lumber Grade Yields For Graded Aspen Logs and Trees" (Hanks and Brisbin 1978).

Log valuation

We stated earlier that log grades were developed to assist buyers and sellers when logs are appraised. In the following examples we demonstrate how the lumber grade yields, thickness distributions, and overruns can be used to predict the value of lumber that can be sawed from a log. We used lumber price quotations from the weekly Hardwood Market Report published by Abe Lemsky.

Species: Yellow Birch
Log grade: 1
Scaling diameter: 13 inches

Lumber grade	Predicted yield[a]	Lumber price per thousand board feet	Lumber value
	Percent	*- - - -Dollars- - - -*	
FAS	16.8	415	69.72
F1F	9.2	405	37.26
SEL	4.6	395	18.17
1 C	29.7	290	86.13
2 C	15.7	185	29.04
3 A	7.5	160	12.00
3 B	16.5	135	22.28
Total			274.60

[a] See table 7.

This figure tells you that 1,000 board feet of 4/4-inch lumber from grade 1, 13 inch yellow birch logs are worth $274.60. If you want to determine lumber value for the thickness distribution presented in table 7, a weighted price for each lumber grade can be calculated as indicated below for FAS:

Thickness class (inches)	Percent of volume	Lumber price per thousand board feet
		Dollars
3/4	1.1	410
4/4	71.3	415
5/4	12.4	420
6/4	5.6	425
8/4	5.5	440
10/4	4.1	450

FAS weighted price = $418.94/M bf.

Weighted prices for all lumber grades could be calculated, and used to determine lumber value per M bf of grade 1, 13-inch yellow birch logs.

The next step is to estimate the lumber volume of the log being considered. A 13-inch, 16-foot log scales 115 board feet by the International 1/4-inch log rule. You may wish to adjust that estimate up or down if

you have reliable overrun figures. From Table 7 we see that an underrun of 1.3 percent was obtained after sawing 48 grade 1 logs that scaled 13 inches. If an underrun of 1.3 percent were subtracted from 115 board feet, a reduced volume of 114 board feet would result.

The last step towards estimating lumber value:

$$\text{lumber value} = \frac{\$274.60 \times 114 \text{ board feet}}{1{,}000 \text{ board feet}}$$

$$\text{lumber value} = \$31.30$$

This figure represents the estimated value of air-dry lumber that can be sawed from a 13-inch, 16-foot, grade 1 yellow birch log. To predict the value of the log at the mill or decked in the woods, subtract the costs of transporting and converting the log into air-dry lumber.

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APPENDIX

Key to Symbols for Tables 1-54

No. logs—actual number of logs sampled

Scale

Int. 1/4-inch rule—International 1/4-inch log rule. Scribner Decimal C rule—Scribner Decimal C log rule. Overrun (Pct.)—lumber tally minus net scale divided by net scale.

NHLA lumber grade yields (actual)—actual lumber grade yields

(green or dry) in percent by National Hardwood Lumber Association lumber grades.

FAS — First and Seconds
F1F — Firsts and Seconds one face
Sel — Select
Saps — Saps, yellow-poplar only
1C — No. 1 Common
2C — No. 2 Common
2A — No. 2A Common
2B — No. 2B Common
SW — Sound wormy
3C — No. 3 Common
3A — No. 3A Common
3B — No. 3B Common
SSE — Sound square edge
TBR — Timbers
WHND — Worm Holes No Defect, chestnut oak only

Index for Lumber Grade Yield Tables

Table No.	Species	Log Grade	Page
1	Basswood	1	10
2	Basswood	2	11
3	Basswood	3	12
4	Paper birch	1	13
5	Paper birch	2	14
6	Paper birch	3	15
7	Yellow birch	1	16
8	Yellow birch	2	18
9	Yellow birch	3	20
10	Black cherry	1	22
11	Black cherry	2	23
12	Black cherry	3	24
13	Red maple	1	26
14	Red maple	2	28
15	Red maple	3	30
16	Sugar maple	1	32
17	Sugar maple	2	34
18	Sugar maple	3	36
19	Black oak	1	38
20	Black oak	2	40
21	Black oak	3	42
22	Chestnut oak	1	44
23	Chestnut oak	2	46
24	Chestnut oak	3	48
25	Northern red oak	1	50
26	Northern red oak	2	51
27	Northern red oak	3	52
28	Scarlet oak	1	54
29	Scarlet oak	2	55
30	Scarlet oak	3	56
31	White oak	1	57
32	White oak	2	58
33	White oak	3	60
34	Yellow-poplar	1	62
35	Yellow-poplar	2	64
36	Yellow-poplar	3	66
37	Beech (green)	1	68
38	Beech (green)	2	70
39	Beech (green)	3	72
40	Cottonwood (green)	1	73
41	Cottonwood (green)	2	74
42	Cottonwood (green)	3	75
43	Elm (green)	1	76
44	Elm (green)	2	78
45	Elm (green)	3	80
46	Sap gum (green)	1	81
47	Sap gum (green)	2	82
48	Sap gum (green)	3	83
49	Lowland red oak (green)	1	84
50	Lowland red oak (green)	2	85
51	Lowland red oak (green)	3	86
52	Lowland white oak (green)	1	88
53	Lowland white oak (green)	2	90
54	Lowland white oak (green)	3	92

Table 1.—BASSWOOD: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber yields (actual)				
		Int. 1/4-inch rule			Scribner Decimal C rule								
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3C
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*				
12	36	2,935	2,751	-1.7	2,480	2,311	17.0	2,704	16.3	16.5	32.2	26.4	8.6
13	40	3,990	3,830	-1.2	3,380	3,222	17.5	3,785	27.0	17.1	26.9	16.9	12.1
14	26	3,070	2,890	-0.6	2,590	2,395	20.0	2,874	22.3	17.9	29.0	25.8	5.0
15	28	3,785	3,628	-2.6	3,420	3,270	8.0	3,532	30.3	17.9	28.3	16.9	6.6
16	32	4,545	4,253	-2.3	4,100	3,797	9.5	4,157	24.3	15.3	29.5	20.5	10.4
17	21	3,790	3,564	3.1	3,400	3,133	17.3	3,674	33.3	17.1	23.7	14.0	11.9
18	20	3,925	3,572	-2.2	3,640	3,218	8.6	3,494	35.8	17.5	16.6	19.7	10.4
19	8	1,800	1,591	-4.4	1,680	1,434	6.1	1,521	43.0	10.5	22.9	12.3	11.3
20	2	385	370	-24.3	380	365	-23.3	280	42.5	15.7	27.9	13.9	—
21	2	390	344	-11.3	380	335	-9.0	305	24.6	11.1	24.3	31.8	8.2
22	3	875	875	-14.9	830	830	-10.2	745	35.9	14.6	26.8	10.1	12.6
23	3	1,040	977	-3.3	1,020	952	-0.7	945	25.2	25.3	17.2	16.0	16.3
All diameters	221	30,530	28,645	-2.2	27,300	25,262	10.9	28,016	28.6	16.8	25.9	18.9	9.8

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3C
1/2	—	—	—	0.1	—
5/8	—	—	—	0.5	—
3/4	5.5	1.6	4.4	4.0	5.8
4/4	61.8	69.6	67.1	71.4	58.3
5/4	15.4	7.1	14.6	12.0	5.9
6/4	2.3	7.6	3.2	0.5	0.4
7/4	—	—	—	0.5	—
8/4	15.0	13.9	10.6	7.2	5.5
9/4	—	0.2	0.1	3.8	23.7
12/4	—	—	—	—	0.4
Total tally (board feet)	8,016	4,703	7,258	5,297	2,742

Table 2.—BASSWOOD: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)				
		Int. 1/4-inch rule			Scribner Decimal C rule								
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	4C
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*				
10	57	2,965	2,797	-0.8	2,370	2,235	24.1	2,774	5.6	9.0	30.7	36.3	18.4
11	138	8,415	7,883	0.7	6,620	6,185	28.4	7,942	7.0	7.5	34.0	38.4	13.1
12	107	7,760	7,294	-1.0	6,640	6,211	16.2	7,219	7.6	9.6	32.0	36.5	14.3
13	88	7,715	7,112	-2.9	6,490	5,953	16.0	6,907	7.9	9.2	31.2	36.9	14.8
14	74	7,405	6,745	-3.6	6,460	5,771	12.6	6,501	11.0	11.1	31.9	33.1	12.9
15	54	6,345	5,707	-4.7	5,850	5,208	4.5	5,440	18.1	10.9	29.0	28.8	13.2
16	20	2,630	2,181	-8.4	2,390	1,965	1.6	1,997	10.9	11.4	32.6	28.9	16.2
17	8	1,210	1,040	-3.8	1,110	931	7.5	1,001	6.9	5.7	38.7	38.6	10.1
18	2	250	233	-2.6	240	219	3.7	227	—	21.1	27.3	28.3	23.3
19	4	800	602	-6.6	750	499	12.6	562	42.6	27.9	12.1	8.0	9.4
20	1	155	155	-27.1	160	160	-29.4	113	43.5	11.5	15.0	26.5	3.5
21	2	390	381	-16.8	380	367	-13.6	317	2.5	4.7	17.7	43.2	31.9
All diameters	555	46,040	42,130	-2.7	39,460	35,704	14.8	41,000	10.0	9.8	31.5	34.6	14.1

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3C
1/2	—	—	—	—	—
5/8	—	—	—	0.2	—
3/4	1.6	1.1	2.3	1.8	1.9
4/4	60.5	75.4	70.4	69.8	62.6
5/4	21.1	6.1	15.2	12.5	8.1
6/4	1.8	4.4	1.2	0.5	—
8/4	15.0	11.7	10.7	11.9	6.1
9/4	—	0.4	0.2	3.3	21.3
10/4	—	0.9	—	—	—
Total tally (board feet)	4,084	4,010	12,915	14,192	5,799

Table 3.—BASSWOOD: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)				
		Int. 1/4-inch rule			Scribner Decimal C rule								
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	SEL	1C	2C	3C
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*				
8	93	2,270	2,173	10.5	1,700	1,626	47.7	2,402	0.1	0.5	13.3	59.0	27.1
9	176	5,995	5,657	5.1	5,100	4,809	23.6	5,946	1.5	3.0	23.4	53.9	18.2
10	150	6,560	6,116	2.8	5,370	4,997	25.8	6,287	1.2	3.1	20.6	57.5	17.6
11	64	3,500	3,230	-1.7	2,850	2,630	20.7	3,175	1.6	4.5	22.6	56.7	14.6
12	37	2,355	2,144	-1.1	2,040	1,824	16.2	2,120	1.1	4.8	17.3	56.1	20.7
13	25	1,835	1,659	-5.3	1,570	1,393	12.8	1,571	6.0	9.5	20.1	47.3	17.1
14	13	1,235	1,159	-0.8	1,080	1,001	14.9	1,150	6.4	10.0	23.7	40.0	19.9
15	14	1,735	1,599	-5.2	1,580	1,415	7.1	1,516	4.1	4.9	20.6	48.5	21.9
16	11	1,445	1,324	3.9	1,320	1,177	16.8	1,375	12.8	13.5	27.0	29.9	16.8
17	7	1,150	1,064	1.0	1,040	938	14.6	1,075	7.0	9.1	21.3	47.3	15.3
18	3	570	539	-11.7	530	490	-2.9	476	9.7	10.3	43.1	29.8	7.1
19	2	380	309	-5.5	360	277	5.4	292	39.4	12.0	2.1	34.2	12.3
All diameters	595	29,030	26,973	1.5	24,540	22,577	21.3	27,385	3.2	4.9	21.2	52.3	18.4

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3C
1/2	—	—	—	—	0.1
5/8	—	—	—	0.1	—
3/4	2.7	0.7	1.2	2.1	0.9
4/4	85.5	81.8	82.6	79.9	70.7
5/4	3.3	2.1	10.2	8.4	5.7
6/4	8.5	8.5	3.2	0.1	0.2
7/4	—	—	—	0.2	—
8/4	—	3.4	2.3	3.0	3.8
9/4	—	3.5	0.5	6.2	18.6
Total tally (board feet)	879	1,336	5,801	14,328	5,041

Table 4.—PAPER BIRCH: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale: Int. 1/4-inch rule Gross	Int. 1/4-inch rule Net	Int. 1/4-inch rule Overrun	Scribner Decimal C rule Gross	Scribner Decimal C rule Net	Scribner Decimal C rule Overrun	Total lumber tally	NHLA lumber grade yields (actual) FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
13	10	1,045	1,027	-14.7	890	874	0.2	876	15.4	25.1	22.4	16.8	13.1	7.2
14	7	835	749	-10.4	710	621	8.1	671	26.4	29.6	14.2	14.5	12.8	2.5
15	10	1,285	1,165	-9.6	1,170	1,034	1.8	1,053	22.8	27.6	19.8	21.0	6.8	2.0
16	6	725	621	3.5	660	545	18.0	643	19.4	28.4	27.8	10.1	6.5	7.8
17	3	375	317	-12.6	360	286	-3.1	277	19.1	19.9	25.7	22.7	6.5	6.1
18	2	310	296	-21.6	290	273	-15.0	232	13.4	28.0	12.9	12.1	18.5	15.1
19	1	155	102	-7.8	150	82	14.6	94	14.9	35.1	29.8	9.6	—	10.6
All diameters	39	4,730	4,277	-10.1	4,230	3,715	3.5	3,846	20.2	27.1	21.0	16.4	9.8	5.5

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
3/4	0.9	1.0	0.2	0.5	5.3	2.3
4/4	99.1	99.0	99.8	99.5	94.7	97.7
Total tally (board feet)	775	1,044	808	630	376	213

Table 5.—PAPER BIRCH: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
10	11	485	449	-4.7	370	337	27.0	428	—	16.6	19.6	25.9	24.8	13.1
11	34	1,935	1,801	-5.3	1,550	1,424	19.8	1,706	6.3	11.7	22.8	23.5	24.9	10.8
12	29	1,840	1,693	-8.4	1,600	1,449	7.0	1,551	5.1	19.3	19.5	27.0	20.3	8.8
13	32	2,540	2,372	-13.0	2,160	1,999	3.2	2,063	6.7	15.5	24.6	28.0	17.2	8.0
14	20	1,820	1,676	-16.3	1,610	1,463	-4.1	1,403	13.8	22.0	19.2	19.0	16.0	10.0
15	20	2,250	2,099	-13.2	2,090	1,921	-5.2	1,821	7.5	13.2	29.4	28.1	13.8	8.0
16	4	500	423	-27.7	460	361	-15.2	306	12.4	24.5	20.6	19.6	20.9	2.0
17	3	315	277	-3.2	300	258	3.9	268	34.7	18.3	20.9	15.7	4.1	6.3
18	2	325	325	-16.3	310	310	-12.3	272	31.2	29.8	13.6	15.8	9.6	—
All diameters	155	12,010	11,115	-11.7	10,450	9,522	3.1	9,818	8.9	16.7	22.8	24.8	18.1	8.7

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
1/2	—	—	0.2	—	—	—
5/8	—	—	—	—	0.2	—
3/4	—	0.8	0.9	2.6	3.2	4.2
4/4	100.0	98.8	98.9	97.4	96.3	95.8
5/4	—	0.4	—	—	0.3	—
Total tally (board feet)	871	1,644	2,242	2,429	1,780	852

Table 6.—PAPER BIRCH: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
8	26	535	500	-3.4	430	405	19.3	483	—	1.7	2.1	15.5	33.7	47.0
9	53	1,625	1,547	-9.0	1,440	1,366	3.1	1,408	—	5.1	6.2	23.7	36.8	28.2
10	53	2,140	1,970	-8.7	1,660	1,505	19.5	1,798	0.3	4.3	9.6	31.1	34.5	20.2
11	31	1,485	1,431	-11.5	1,210	1,159	9.2	1,266	—	5.8	16.0	28.2	27.9	22.1
12	26	1,540	1,418	-11.6	1,330	1,218	3.0	1,254	1.5	7.3	11.1	25.4	33.3	21.4
13	20	1,460	1,307	-27.2	1,240	1,069	-11.0	951	5.6	7.3	20.0	28.2	19.2	19.7
14	18	1,535	1,394	-19.2	1,370	1,228	-8.2	1,127	0.4	4.5	25.3	27.5	23.7	18.6
15	8	760	655	-21.5	710	592	-13.2	514	—	10.1	30.5	15.8	22.0	21.6
16	7	735	700	-24.6	660	625	-15.5	528	4.2	7.6	29.7	24.8	17.4	16.3
17	2	300	280	-30.4	280	256	-23.8	195	37.5	11.8	8.2	16.9	16.9	8.7
18	3	480	325	-5.2	450	268	14.9	308	3.9	8.4	24.4	21.1	30.5	11.7
19	1	225	198	-5.1	210	179	5.0	188	8.5	1.6	55.8	30.9	1.1	2.1
All diameters	248	12,820	11,725	-14.5	10,990	9,870	1.5	10,020	2.0	5.8	15.9	25.9	28.6	21.8

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
1 2	—	—	—	—		0.2
3 4	—	1.5	1.8	1.7	3.1	4.8
4 4	100.0	98.5	98.2	98.1	96.6	95.0
5 4	—	—	—	0.2	0.3	—
Total tally (board feet)	205	585	1,592	2,591	2,858	2,186

Table 7.—YELLOW BIRCH: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
13	48	4,595	4,401	-1.3	3,880	3,709	17.1	4,344	16.8	9.2	4.6	29.7	15.7	7.5	16.5
14	45	5,275	5,000	-6.0	4,500	4,237	11.0	4,702	22.7	8.7	3.3	29.8	16.4	5.8	13.3
15	47	6,090	5,852	-4.9	5,560	5,309	4.8	5,566	22.1	12.1	3.2	28.7	13.9	5.2	14.8
16	64	9,725	9,184	-4.7	8,780	8,230	6.4	8,755	23.0	9.0	2.2	31.5	14.8	7.3	12.2
17	63	10,430	9,740	-5.3	9,490	8,837	4.4	9,226	27.9	9.6	2.0	29.3	12.4	6.0	12.8
18	49	9,305	8,987	-2.2	8,750	8,413	4.5	8,793	35.5	10.2	2.0	26.2	10.9	5.5	9.7
19	37	7,855	7,561	-3.1	7,360	7,071	3.7	7,330	40.1	8.8	2.2	26.4	9.4	4.5	8.6
20	19	4,035	3,830	-3.4	3,930	3,684	0.5	3,701	31.8	11.6	3.1	31.7	9.8	4.1	7.9
21	17	4,150	4,064	-6.5	4,010	3,923	-3.1	3,801	38.7	7.5	1.8	25.8	12.2	6.7	7.3
22	10	2,880	2,655	-7.6	2,740	2,485	-1.3	2,453	52.9	5.4	2.1	21.2	6.8	5.7	5.9
23	4	1,350	1,264	-4.6	1,320	1,236	-2.4	1,206	46.1	11.0	5.1	20.6	7.0	3.6	6.6
24	4	1,415	1,356	-2.8	1,350	1,279	3.0	1,318	22.5	6.7	0.7	35.4	13.8	10.4	10.5
25	2	620	554	-20.9	630	547	-19.9	438	32.5	7.5	0.7	25.8	20.1	5.9	7.5
26	2	740	613	0.5	750	594	3.7	616	43.1	4.2	3.4	28.9	9.6	6.3	4.5
27	1	540	540	-9.6	550	550	-11.3	488	58.6	10.5	1.0	17.0	6.4	4.5	2.0
All diameters	412	69,005	65,601	-4.4	63,600	60,104	4.4	62,737	30.5	9.4	2.5	28.3	12.4	5.9	11.0

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
3/8	—	—	—	—	—	—	—
1/2	—	0.1	—	—	—	—	—
5/8	—	—	—	0.1	—	—	0.1
3/4	1.1	1.2	2.7	3.2	2.4	2.1	2.0
4/4	71.3	62.1	66.9	73.5	72.0	71.9	64.8
5/4	12.4	15.8	14.4	10.2	12.8	12.0	5.7
6/4	5.6	9.2	10.1	5.4	3.7	1.9	3.5
8/4	5.5	5.3	5.5	5.3	4.5	9.0	19.6
9/4	—	—	—	—	0.2	1.1	2.6
10/4	4.1	6.3	0.4	2.3	2.0	1.0	0.3
12/4	—	—	—	—	—	—	1.2
16/4	—	—	—	—	2.4	1.0	0.2
Total tally (board feet)	19,156	5,871	1,579	17,770	7,758	3,701	6,902

Table 8.—YELLOW BIRCH: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
10	49	2,670	2,480	4.7	2,160	1,997	30.0	2,597	3.4	2.5	1.5	24.9	24.3	13.4	30.0
11	124	7,990	7,387	0.4	6,260	5,783	28.3	7,420	4.0	4.6	2.6	26.5	20.2	11.7	30.4
12	161	12,060	11,170	-2.3	10,280	9,506	14.8	10,914	7.4	6.7	2.6	25.2	21.2	12.1	24.8
13	113	9,925	9,111	-7.0	8,310	7,568	12.0	8,477	5.5	4.6	1.9	27.3	23.6	12.6	24.5
14	103	10,510	9,632	-7.9	9,140	8,310	6.8	8,871	7.1	6.6	1.6	30.2	23.0	11.1	20.4
15	105	12,415	11,493	-8.3	11,440	10,522	0.1	10,537	10.8	8.3	1.8	27.5	22.8	10.2	18.6
16	46	6,210	5,589	-3.4	5,650	4,997	8.0	5,399	11.6	6.7	1.2	28.1	25.8	11.1	15.5
17	33	4,980	4,395	-4.7	4,550	3,927	6.7	4,190	5.7	4.7	1.1	31.5	24.8	11.4	20.8
18	25	4,340	3,919	-13.8	4,080	3,656	-7.6	3,377	12.5	8.4	1.9	36.0	18.2	6.6	16.4
19	24	4,330	3,939	-0.2	4,100	3,619	8.7	3,933	9.4	7.3	1.4	38.2	21.1	10.5	12.1
20	8	1,615	1,487	-16.3	1,590	1,417	-12.1	1,245	6.7	10.5	3.4	36.9	22.9	9.2	10.4
21	4	865	843	-2.1	830	820	0.6	825	18.3	4.0	—	49.3	16.1	4.4	7.9
22	4	905	733	-8.9	880	691	-3.3	668	19.0	9.3	2.7	34.1	15.7	6.6	12.6
23	5	1,325	1,223	-21.4	1,320	1,218	-21.1	961	18.2	4.7	0.6	39.7	22.4	2.7	11.7
24	1	310	305	-21.3	300	295	-18.6	240	9.6	7.9	1.7	59.5	12.5	4.6	4.2
25	2	740	740	-7.0	740	740	-7.0	688	36.7	10.0	0.3	35.6	10.3	4.9	2.2
All diameters	807	81,190	74,446	-5.5	71,630	65,066	8.1	70,342	8.4	6.3	1.8	29.4	22.2	10.9	21.0

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
3/8	—	—	—	—	—	—	—
1/2	—	—	—	—	0.1	—	—
5/8	—	—	—	0.1	—	—	0.1
3/4	1.5	1.7	3.8	4.3	2.7	2.1	2.4
4/4	70.6	64.7	66.7	76.3	71.9	79.0	68.7
5/4	13.8	15.9	15.8	8.7	10.1	9.0	4.5
6/4	8.3	12.2	10.4	5.6	4.2	2.0	3.5
8/4	4.1	2.6	2.8	2.8	3.8	5.6	14.4
9/4	—	—	—	—	—	0.3	3.8
10/4	1.7	2.9	0.5	1.3	2.1	2.0	0.5
12/4	—	—	—	—	2.8	—	1.0
16/4	—	—	—	0.9	2.3	—	1.1
Total tally (board feet)	5,893	4,463	1,298	20,677	15,618	7,648	14,745

Table 9.—YELLOW BIRCH: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
8	42	995	952	8.7	740	704	47.0	1,035	—	0.4	0.7	7.4	19.9	19.0	52.6
9	93	3,170	2,899	5.2	2,700	2,457	24.1	3,049	0.3	0.4	1.3	10.7	24.4	21.7	41.2
10	153	6,795	6,175	-1.9	5,400	4,888	23.9	6,055	0.6	1.3	1.3	13.9	23.1	17.9	41.9
11	89	4,580	4,163	-2.2	3,680	3,322	22.5	4,070	0.5	1.2	1.5	13.2	30.9	20.6	32.1
12	63	3,950	3,517	-8.1	3,420	3,016	7.1	3,231	0.2	1.5	0.5	14.3	28.2	20.6	34.7
13	48	3,830	3,381	-9.6	3,240	2,819	8.4	3,057	—	2.1	1.1	18.2	34.8	21.8	22.0
14	32	3,015	2,749	-13.8	2,660	2,396	-1.1	2,369	0.9	1.8	1.1	20.5	27.8	14.9	33.0
15	27	2,800	2,385	-15.2	2,630	2,159	-6.3	2,023	1.3	1.2	0.6	17.0	27.4	19.4	33.1
16	14	1,845	1,664	-11.8	1,680	1,451	1.2	1,468	5.9	5.0	1.6	20.7	24.3	11.8	30.7
17	11	1,465	1,214	-12.7	1,360	1,050	1.0	1,060	2.5	4.8	1.2	18.8	24.2	22.5	26.0
18	10	1,520	1,217	-15.9	1,450	1,092	-6.2	1,024	4.7	8.6	4.1	21.3	27.2	15.0	19.1
19	3	375	335	0.9	360	304	11.2	338	—	5.9	3.0	29.3	27.8	20.4	13.6
20	3	520	491	-10.2	520	477	-7.5	441	2.3	5.7	—	45.9	22.7	15.2	8.2
21	2	515	409	7.8	490	371	18.9	441	7.3	2.7	—	31.1	30.8	15.9	12.2
22	3	690	666	-13.5	670	637	-9.6	576	4.3	6.3	—	28.6	17.0	11.1	32.7
23	1	335	335	-4.8	330	330	-3.3	319	18.8	11.6	—	33.6	28.8	3.4	3.8
24	1	425	387	7.5	400	349	19.2	416	39.2	—	1.4	28.1	22.6	6.5	2.2
All diameters	595	36,825	32,939	-6.0	31,730	27,822	11.3	30,972	1.9	2.1	1.2	16.7	26.8	18.5	32.8

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
3/8	—	—	—	—	—	—	0.1
1/2	—	—	1.0	—	—	—	0.1
5/8	—	—	—	—	—	—	0.1
3/4	2.4	0.4	0.3	2.0	2.2	2.2	2.8
4/4	80.3	68.8	77.3	80.2	74.8	83.0	78.9
5/4	17.3	26.4	14.7	14.9	9.8	12.1	5.4
6/4	—	4.4	2.8	1.8	2.5	0.5	2.5
8/4	—	—	—	0.6	1.2	1.7	6.6
9/4	—	—	—	—	—	—	1.8
10/4	—	—	3.9	0.5	1.3	0.5	0.4
12/4	—	—	—	—	7.5	—	—
16/4	—	—	—	—	0.7	—	1.3
Total tally (board feet)	577	661	366	5,179	8,299	5,732	10,158

Table 10.—BLACK CHERRY: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale: Int. 1/4-inch rule Gross	Int. 1/4-inch rule Net	Int. 1/4-inch rule Overrun	Scribner Decimal C rule Gross	Scribner Decimal C rule Net	Scribner Decimal C rule Overrun	Total lumber tally	NHLA lumber grade yields (actual) FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
13	19	1,675	1,614	1.3	1,390	1,331	22.8	1,635	28.2	28.5	15.8	13.1	8.0	6.4
14	24	2,540	2,503	2.8	2,200	2,163	19.0	2,574	27.8	27.3	18.1	13.7	9.9	3.2
15	24	3,115	3,016	0.8	2,820	2,719	11.8	3,041	38.5	21.8	16.0	13.1	8.3	2.3
16	30	4,120	3,957	-0.7	3,740	3,570	10.0	3,928	34.5	20.0	18.9	15.7	7.2	3.7
17	23	3,435	3,328	-1.7	3,180	3,080	6.2	3,272	30.8	25.7	21.5	10.8	7.3	3.9
18	19	3,215	3,045	-3.0	3,000	2,802	5.5	2,955	37.3	20.3	21.3	12.4	4.1	4.6
19	19	4,065	3,990	0.7	3,810	3,718	8.1	4,018	41.5	20.8	16.5	12.1	5.6	3.5
20	13	2,830	2,725	3.1	2,760	2,661	5.6	2,810	30.5	28.4	19.3	13.5	5.8	2.5
21	4	945	930	-5.9	920	903	-3.1	875	42.6	21.1	17.7	9.0	7.4	2.2
22	4	950	904	2.3	920	861	7.4	925	47.8	17.3	11.1	12.4	4.6	6.8
24	2	565	475	-11.2	550	460	-8.3	422	49.7	17.3	19.2	3.8	1.2	8.8
25	3	960	900	-3.8	970	897	-3.5	866	38.7	21.2	21.0	7.6	7.6	3.9
All diameters	184	28,415	27,387	-0.2	26,260	25,165	8.6	27,321	35.5	23.0	18.3	12.6	6.8	3.8

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
1/2	—	—	0.1	0.1	—	0.5
3/4	0.4	0.1	0.1	—	0.4	1.9
4/4	42.8	49.7	70.2	84.8	77.2	85.9
5/4	2.2	2.9	2.6	3.0	1.8	—
6/4	23.7	19.9	17.3	6.4	2.5	—
7/4	—	—	—	—	0.5	—
8/4	30.9	27.4	9.7	5.3	17.6	11.7
12/4	—	—	—	0.4	—	—
Total tally (board feet)	9,701	6,291	5,010	3,443	1,851	1,025

Table 11.—BLACK CHERRY: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
10	9	455	455	5.7	350	350	37.4	481	9.4	20.4	23.0	22.7	16.8	7.7
11	42	2,270	2,159	3.4	1,800	1,723	29.6	2,233	4.9	10.0	27.5	26.4	19.8	11.4
12	65	4,405	4,230	-0.7	3,800	3,641	15.4	4,201	7.3	16.0	25.9	27.6	16.1	7.1
13	49	3,920	3,743	-1.8	3,270	3,086	19.1	3,676	7.2	14.5	31.1	25.5	15.9	5.8
14	42	3,620	3,475	-5.8	3,220	3,101	5.6	3,275	11.2	17.6	32.2	20.3	12.4	6.3
15	36	4,010	3,891	-5.5	3,680	3,557	3.4	3,678	8.7	19.2	33.6	22.4	10.1	6.0
16	19	2,130	2,046	-5.4	1,960	1,874	3.3	1,935	9.8	16.0	35.1	20.2	8.1	10.8
17	20	2,830	2,737	-2.4	2,600	2,498	7.0	2,672	7.9	19.7	36.8	21.4	12.0	2.2
18	15	2,565	2,428	-3.3	2,400	2,271	3.3	2,347	12.4	17.9	40.5	17.3	8.5	3.4
19	8	1,565	1,441	-11.3	1,460	1,337	-4.4	1,278	11.8	11.8	40.3	20.6	10.4	5.1
20	5	945	865	1.6	930	851	3.3	879	10.0	19.9	35.8	17.6	11.5	5.2
21	2	350	275	12.0	340	267	15.4	308	27.3	23.4	25.3	14.6	4.9	4.5
All diameters	312	29,065	27,745	-2.8	25,810	24,556	9.8	26,963	9.0	16.6	32.5	22.7	12.9	6.3

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
5/8	–	–	–	–	0.2	–
3/4	0.4	0.4	0.2	0.3	1.0	0.5
4/4	69.4	66.1	80.9	91.7	70.5	85.6
5/4	1.2	3.0	1.8	1.2	0.1	0.8
6/4	11.4	15.6	9.5	4.0	2.0	0.5
7/4	–	–	–	–	–	0.6
8/4	17.6	14.9	7.6	2.8	23.6	10.2
12/4	–	–	–	–	2.6	1.8
Total tally (board feet)	2,122	4,467	8,764	6,115	3,491	1,704

Table 12.—BLACK CHERRY: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
8	34	710	650	12.3	560	513	42.3	730	—	2.3	4.2	29.7	42.6	21.2
9	52	1,515	1,437	8.5	1,350	1,268	22.9	1,559	—	3.2	10.1	36.4	33.5	16.8
10	75	3,115	2,979	-0.6	2,520	2,398	23.5	2,962	1.1	3.2	15.7	40.9	29.8	9.3
11	55	2,665	2,508	-3.7	2,150	2,013	20.0	2,415	0.9	3.5	19.7	39.0	27.0	9.9
12	45	2,535	2,378	-1.9	2,190	2,022	15.3	2,332	1.0	3.7	24.0	37.4	21.6	12.3
13	22	1,625	1,493	-2.9	1,380	1,253	15.7	1,450	1.4	6.7	26.1	37.9	18.0	9.9
14	28	2,450	2,351	-4.6	2,170	2,060	8.9	2,243	4.8	8.8	27.1	33.8	18.1	7.4
15	15	1,535	1,424	-4.6	1,420	1,316	3.2	1,358	4.0	3.4	43.5	29.5	14.7	4.9
16	10	1,085	1,014	-3.7	1,000	924	5.6	976	6.1	7.9	43.0	21.5	12.0	9.5
17	2	275	275	-8.4	260	260	-3.1	252	5.2	7.9	55.1	14.3	12.7	4.8
18	5	610	545	-9.7	590	529	-7.0	492	13.4	7.3	41.7	19.1	9.6	8.9
19	1	125	115	-8.7	120	110	-4.5	105	—	—	76.1	12.4	2.9	8.6
20	1	175	155	-7.7	170	150	-4.7	143	38.4	16.8	16.1	16.1	8.4	4.2
All diameters	345	18,520	17,324	-1.8	15,880	14,816	14.9	17,017	2.7	4.9	24.3	34.6	23.2	10.3

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
3 8	—	—	0.1	—	0.1	—
1 2	—	—	—	0.1	—	0.1
5 8	—	0.3	—	—	—	—
3 4	—	—	0.2	0.3	0.5	0.3
4 4	82.2	83.3	89.4	91.9	67.9	83.7
5 4	1.3	3.9	1.4	2.6	0.3	0.4
6 4	13.1	9.3	8.3	2.4	0.6	0.4
7 4	—	—	—	—	0.3	—
8 4	3.4	3.2	0.6	2.7	27.3	14.3
12 4	—	—	—	—	3.0	0.8
Total tally (board feet)	455	829	4,129	5,898	3,946	1,760

Table 13.—RED MAPLE: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2A	2B	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
13	25	2,455	2,380	-4.2	2,060	1,991	14.5	2,279	17.2	14.6	5.0	27.3	17.6	7.9	6.7	3.7
14	25	2,910	2,747	3.1	2,470	2,297	23.3	2,833	21.6	19.6	5.8	15.5	21.1	11.1	3.7	1.6
15	27	3,760	3,686	-4.3	3,380	3,296	7.0	3,526	25.4	17.0	7.9	18.1	14.2	10.2	6.1	1.1
16	31	4,590	4,447	-0.7	4,140	3,962	11.4	4,414	25.4	16.3	4.6	20.8	18.7	9.0	3.0	2.2
17	29	4,910	4,713	-4.3	4,440	4,239	6.4	4,510	25.5	15.1	3.2	26.9	18.9	7.1	2.1	1.2
18	15	2,580	2,520	-0.9	2,420	2,343	6.6	2,497	30.8	18.3	8.2	20.7	15.8	2.7	2.3	1.2
19	12	2,630	2,541	-1.0	2,460	2,350	7.0	2,515	31.1	13.9	4.2	19.1	15.0	12.8	3.1	0.8
20	8	1,920	1,872	-2.4	1,880	1,820	0.4	1,828	34.4	19.4	5.6	19.0	17.0	2.5	1.8	0.3
21	4	900	865	-5.0	880	830	-1.0	822	32.3	19.5	3.5	23.7	15.0	3.2	1.5	1.3
22	3	825	798	-0.1	790	764	4.3	797	19.1	6.6	2.3	42.8	12.4	2.5	8.0	6.3
23	1	285	285	10.5	280	280	12.5	315	50.4	10.2	9.5	12.1	15.6	2.2	—	—
24	1	310	310	-14.5	300	300	-11.7	265	7.9	9.8	3.4	38.5	30.6	—	3.8	6.0
25	1	400	265	2.3	400	265	2.3	271	13.3	1.5	0.4	46.1	25.8	11.8	0.7	0.4
All diameters	182	28,475	27,429	-2.0	25,900	24,737	8.6	26,872	26.0	16.1	5.2	22.2	17.4	7.8	3.6	1.7

Percentage distribution of grade 1 logs yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2A	2B	3A	3B
1 2	—	—	—	0.1	0.1	0.1	—	—
5 8	—	—	—	—	—	—	0.2	—
3 4	0.2	0.6	—	0.7	0.5	1.7	1.5	1.7
4 4	56.0	66.1	69.1	67.4	52.9	58.3	62.7	70.4
5 4	10.9	8.5	5.8	11.5	12.3	14.7	5.1	2.6
6 4	13.6	13.1	13.5	7.1	1.5	1.5	1.9	3.6
7 4	—	—	—	0.1	0.1	0.3	0.3	3.9
8 4	19.3	11.7	11.6	13.1	11.6	11.3	19.3	17.8
10 4	—	—	—	—	0.3	12.1	9.0	—
12 4	—	—	—	—	20.3	—	—	—
24 4	—	—	—	—	0.4	—	-	-
Total tally (board feet)	6,988	4,322	1,404	5,978	4,678	2,090	955	457

Table 14.—RED MAPLE: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2A	2B	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
10	11	595	563	3.4	460	428	36.0	582	11.3	9.5	5.2	18.2	20.1	16.5	8.2	11.0
11	74	1,715	4,546	0.8	3,880	3,685	24.4	4,584	2.9	6.9	3.5	21.5	31.4	18.9	6.9	8.0
12	88	6,650	6,297	-1.4	5,650	5,315	16.9	6,211	5.8	9.0	4.7	22.9	29.6	16.3	6.9	4.8
13	70	6,135	5,722	-2.7	5,210	4,768	16.7	5,565	4.7	9.9	4.5	19.9	39.5	10.6	6.1	4.8
14	58	5,480	5,140	-4.4	4,820	4,437	10.8	4,916	7.3	10.8	4.4	25.1	28.9	11.7	7.2	4.6
15	46	5,340	5,016	-3.2	4,900	4,516	7.5	4,855	11.4	12.7	2.6	25.4	27.5	11.8	4.2	4.4
16	32	4,120	3,833	-1.0	3,760	3,450	10.0	3,795	8.7	11.2	3.0	31.0	33.2	6.2	4.2	2.5
17	19	2,515	2,375	4.0	2,360	2,206	11.9	2,469	8.3	9.1	3.0	32.8	27.4	9.7	5.2	4.5
18	9	1,485	1,351	-12.1	1,400	1,242	-4.3	1,188	14.1	5.7	4.0	30.6	27.2	5.0	9.4	4.0
19	8	1,660	1,515	-9.7	1,560	1,374	-0.4	1,368	22.3	11.5	4.3	27.0	22.1	6.1	5.7	1.0
20	4	845	826	-9.0	830	806	-6.7	752	36.6	19.1	4.5	14.2	17.0	0.7	3.2	4.7
21	5	1,145	993	-7.9	1,100	908	0.8	915	30.4	14.4	8.0	19.8	16.7	2.7	5.6	2.4
All diameters	424	40,715	38,177	-2.6	35,930	33,135	12.3	37,200	8.8	10.2	4.0	24.5	30.1	11.7	6.0	4.7

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2A	2B	3A	3B
1/2	—	—	—	0.1	—	—	0.2	—
3/4	0.1	0.3	—	0.7	0.7	1.8	0.8	0.6
4/4	63.5	61.5	66.1	74.8	60.7	63.7	68.0	70.1
5/4	9.7	15.0	14.1	8.7	8.9	13.9	4.3	3.5
6/4	13.5	15.3	15.3	7.4	1.4	—	1.5	—
7/4	—	0.2	—	0.1	0.4	—	0.4	2.7
8/4	13.2	7.7	4.5	8.2	6.4	12.9	23.7	19.9
9/4	—	—	—	—	0.1	0.2	—	1.2
10/4	—	—	—	—	0.7	7.5	1.1	—
12/4	—	—	—	—	19.5	—	—	2.0
24/4	—	—	—	—	1.2	—	—	—
Total tally (board feet)	3,290	3,778	1,471	9,099	11,202	4,361	2,238	1,761

Table 15.—RED MAPLE: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1 4-inch rule			Scribner Decimal C Rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2A	2B	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
8	67	1,630	1,578	9.3	1,300	1,254	37.5	1,724	—	0.1	0.3	2.6	20.0	44.1	14.4	18.5
9	116	3,880	3,729	2.0	3,370	3,225	17.9	3,803	0.2	0.9	1.6	6.2	31.8	36.3	12.4	10.6
10	163	7,160	6,839	-1.2	5,770	5,489	23.1	6,756	0.6	1.1	2.4	9.8	31.8	35.1	11.5	7.7
11	94	5,010	4,799	-0.5	4,060	3,866	23.6	4,777	0.4	0.8	1.5	9.5	36.4	34.2	9.7	7.5
12	67	4,175	3,925	-4.2	3,620	3,388	11.0	3,762	0.5	1.4	1.2	13.3	39.2	24.2	13.2	7.0
13	51	3,980	3,738	-6.4	3,370	3,150	11.0	3,497	1.5	4.6	1.3	14.2	39.2	27.6	7.1	4.5
14	35	3,100	2,823	-11.9	2,740	2,447	1.6	2,487	1.4	4.5	1.1	17.8	36.9	22.1	11.9	4.3
15	18	1,905	1,781	-5.3	1,770	1,626	3.7	1,686	6.3	8.4	0.9	31.9	29.7	11.8	8.2	2.8
16	7	890	850	-15.5	810	774	-7.2	718	—	10.7	0.8	21.0	47.7	11.4	7.8	0.6
17	7	1,015	949	-0.1	940	869	9.1	948	12.8	14.0	3.9	21.1	19.2	9.4	16.5	3.1
18	4	620	531	-2.4	580	490	5.7	518	10.2	6.0	2.1	38.5	21.0	7.3	6.0	8.9
19	1	190	190	-3.2	180	180	2.2	184	—	—	—	23.9	46.2	9.8	1.6	18.5
All diameters	630	33,555	31,732	-2.7	28,510	26,758	15.3	30,860	1.5	2.8	1.6	12.8	33.7	29.2	11.0	7.4

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2A	2B	3A	3B
1/2	—	—	—	0.1	—	—	—	0.1
5/8	—	—	—	—	—	—	—	0.1
3/4	—	—	—	1.3	0.5	2.8	1.5	1.6
4/4	75.5	75.1	75.5	81.1	60.0	72.7	64.6	82.0
5/4	5.8	12.1	14.5	8.2	8.5	10.5	4.7	3.3
6/4	18.7	7.6	9.2	5.4	0.9	0.2	0.2	0.5
7/4	—	2.2	—	—	—	—	—	—
8/4	—	3.0	0.8	3.9	2.6	3.4	12.0	12.4
10/4	—	—	—	—	0.3	10.4	17.0	—
12/4	—	—	—	—	25.0	—	—	—
24/4	—	—	—	—	2.2	—	—	—
Total tally (board feet)	450	854	488	3,965	10,429	9,003	3,386	2,285

Table 16.—SUGAR MAPLE: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
13	56	5,410	5,145	3.4	4,530	4,302	23.7	5,322	14.7	13.2	4.1	26.7	14.2	10.5	16.6
14	47	5,290	5,109	4.3	4,540	4,384	21.6	5,329	23.2	12.7	4.4	24.7	15.1	7.0	12.9
15	54	7,295	6,980	-3.7	6,600	6,302	6.6	6,719	24.2	11.7	3.5	23.7	14.1	8.5	14.3
16	66	9,360	9,114	-5.0	8,490	8,250	4.9	8,658	19.5	11.5	3.1	27.5	17.0	6.9	14.5
17	74	12,370	11,876	-6.1	11,230	10,716	4.1	11,155	20.9	13.0	3.4	28.1	16.6	5.9	12.1
18	56	10,600	10,220	-5.5	9,880	9,473	1.9	9,656	24.3	13.2	3.1	25.0	15.7	6.0	12.7
19	34	7,250	7,010	-8.0	6,790	6,550	-1.5	6,452	21.4	11.7	2.6	28.1	17.3	6.5	12.4
20	47	11,275	10,922	-4.7	10,960	10,550	-1.3	10,409	26.6	13.1	2.7	25.8	15.6	7.1	9.1
21	22	5,545	5,417	-7.2	5,350	5,197	-3.3	5,025	27.7	13.9	2.8	26.8	14.4	7.1	7.3
22	14	4,260	4,085	-6.0	4,020	3,821	0.5	3,839	20.9	8.9	3.2	31.6	19.2	7.2	9.0
23	8	2,590	2,340	-9.2	2,540	2,252	-5.7	2,124	35.7	12.5	2.8	24.2	10.5	6.8	7.5
24	1	310	207	-7.7	300	200	-4.5	191	52.8	5.2	1.6	23.6	8.9	6.3	1.6
25	2	800	700	4.0	800	700	4.0	728	31.5	7.7	1.8	24.5	21.6	5.6	7.3
26	1	500	500	-17.2	500	500	-17.2	414	49.9	10.9	2.7	18.4	16.9	1.0	0.2
All diameters	482	82,855	79,625	-4.5	76,530	73,197	3.9	76,021	23.2	12.4	3.2	26.5	15.8	7.0	11.9

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
5/8	—	—	—	—	—	—	0.1
3/4	0.2	0.2	0.6	0.3	1.2	0.5	0.4
4/4	19.6	20.6	34.6	35.7	44.6	52.1	59.0
5/4	23.8	37.1	18.2	31.5	21.8	17.5	9.4
6/4	23.6	—	7.4	5.6	3.2	2.5	5.6
7/4	0.3	—	0.7	0.1	0.3	—	0.4
8/4	24.4	37.1	35.3	24.0	25.4	22.3	19.4
9/4	1.8	1.7	0.9	1.0	0.3	—	—
10/4	4.0	1.6	1.1	0.7	—	—	0.7
12/4	2.3	1.7	1.2	0.8	2.7	—	2.1
16/4	—	—	—	—	0.3	4.6	2.9
24/4	—	—	—	0.3	0.2	0.5	—
Total tally (board feet)	17,657	9,438	2,440	20,110	12,006	5,323	9,047

Table 17.—SUGAR MAPLE: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
10	35	1,770	1,690	2.9	1,420	1,353	28.5	1,739	2.8	3.7	2.5	25.3	19.3	11.2	35.2
11	152	9,480	9,124	1.0	7,480	7,192	28.1	9,214	3.2	5.5	2.5	22.8	21.1	11.5	33.4
12	220	16,800	16,147	-3.9	14,290	13,746	12.9	15,519	5.3	4.7	2.0	25.9	22.0	11.3	28.8
13	211	18,585	17,867	-5.1	15,630	15,005	13.0	16,958	4.2	4.4	1.8	24.9	25.6	12.8	26.3
14	151	15,750	15,070	-5.9	13,670	13,060	8.6	14,177	4.7	4.7	2.8	29.5	25.3	10.7	22.3
15	157	19,000	18,258	-7.3	17,470	16,752	1.1	16,930	6.6	6.9	2.8	28.1	25.3	9.7	20.6
16	96	12,990	12,139	-6.1	11,810	10,977	3.9	11,400	6.0	5.2	2.7	31.1	26.8	9.7	18.5
17	86	13,155	12,360	-6.5	12,070	11,271	2.5	11,558	6.3	8.5	2.4	31.9	22.3	11.1	17.5
18	44	8,125	7,672	-7.1	7,600	7,133	-0.1	7,127	5.8	7.8	1.7	33.1	24.6	9.1	17.9
19	38	7,450	6,981	-9.0	7,010	6,518	-2.5	6,352	10.3	10.8	2.0	30.6	25.6	10.4	10.3
20	30	6,320	5,967	-9.0	6,260	5,861	-7.4	5,430	8.9	11.0	2.7	30.1	22.0	10.7	14.6
21	13	3,470	3,250	-3.0	3,310	3,039	3.7	3,152	19.3	6.4	3.2	28.9	18.4	10.1	13.7
22	3	805	706	-7.2	770	675	-3.0	655	14.2	9.6	3.5	23.2	25.7	11.0	12.8
23	1	390	267	17.2	380	260	20.4	313	22.7	4.8	1.0	19.5	30.3	5.4	16.3
All diameters	1,237	134,090	127,498	-5.5	119,170	112,842	6.8	120,524	6.2	6.3	2.4	28.2	24.0	10.8	22.1

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1/2	—	—	—	—	—	—	—
5/8	—	0.2	—	0.1	—	—	0.1
3/4	0.3	0.2	1.2	0.4	0.6	0.5	0.3
4/4	26.6	23.0	36.5	44.1	46.5	56.9	55.5
5/4	24.9	40.9	22.9	30.7	22.7	18.5	7.7
6/4	24.5	—	9.9	5.9	4.1	3.8	4.9
7/4	—	0.2	—	0.1	0.2	—	0.1
8/4	20.8	35.0	29.1	18.2	20.8	16.2	22.1
9/4	0.5	0.2	0.2	0.2	0.1	0.2	1.4
10/4	1.3	0.3	0.2	0.1	0.1	—	0.1
12/4	1.1	—	—	0.2	4.4	—	5.6
16/4	—	—	—	—	0.5	3.9	2.2
Total tally (board feet)	7,396	7,610	2,864	33,997	28,955	13,026	26,676

Table 18.—SUGAR MAPLE: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
8	20	505	488	10.0	410	396	35.6	537	—	0.4	1.7	6.0	26.1	15.3	50.5
9	79	2,900	2,788	9.8	2,440	2,348	30.3	3,060	1.4	0.7	0.5	10.6	21.1	24.2	41.5
10	124	5,570	5,305	3.3	4,490	4,273	28.2	5,479	0.3	0.8	1.4	13.5	24.2	20.0	39.8
11	92	4,885	4,675	2.9	3,950	3,777	27.3	4,810	—	0.6	0.8	11.0	27.3	18.9	41.4
12	74	5,095	4,820	-1.6	4,370	4,130	14.8	4,742	0.6	1.1	2.0	14.0	29.1	21.2	32.0
13	73	5,810	5,474	-8.9	4,940	4,641	7.4	4,986	0.7	1.1	1.1	14.1	29.3	19.2	34.5
14	63	5,920	5,579	-7.4	5,190	4,875	6.0	5,166	1.0	0.9	2.2	15.2	29.0	16.4	35.3
15	50	5,640	5,163	-9.6	5,170	4,664	—	4,666	0.8	5.4	1.6	23.0	28.3	14.5	26.4
16	35	4,035	3,728	-8.6	3,710	3,392	0.4	3,406	1.2	2.8	1.2	29.5	29.7	14.4	21.2
17	27	3,700	3,423	-14.3	3,430	3,130	-6.3	2,933	0.7	4.5	2.3	22.8	32.0	20.4	17.3
18	19	3,590	3,194	-10.8	3,360	2,948	-3.3	2,850	1.5	6.1	1.5	23.8	29.8	16.3	21.0
19	14	2,550	2,465	-0.9	2,410	2,321	5.3	2,444	2.1	7.8	1.2	32.2	29.3	10.1	17.3
20	2	385	341	-7.3	360	302	4.6	316	—	2.2	3.2	22.8	36.7	17.1	18.0
21	5	1,020	908	-11.6	980	860	-6.6	803	1.2	3.0	0.5	37.8	29.1	12.0	16.4
All diameters	677	51,605	48,351	-4.5	45,210	42,057	9.8	46,198	0.8	2.4	1.5	18.1	28.0	17.9	31.3

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1/2	—	—	—	—	—	—	0.1
5/8	1.0	—	—	—	—	—	—
3/4	—	—	1.9	0.6	0.5	0.6	0.3
4/4	34.0	20.2	49.4	48.6	51.8	56.0	54.0
5/4	29.4	51.1	22.7	35.5	23.3	19.6	8.6
6/4	4.2	—	1.0	1.0	2.6	1.7	2.3
7/4	4.0	—	—	0.4	0.2	—	0.3
8/4	27.4	26.6	25.0	13.7	11.4	11.6	22.3
9/4	—	2.1	—	0.2	—	—	1.0
10/4	—	—	—	—	0.3	—	0.2
12/4	—	—	—	—	8.6	—	7.2
16/4	—	—	—	—	1.3	10.5	3.7
Total tally (board feet)	384	1,118	668	8,362	12,949	8,265	14,452

Table 19.—BLACK OAK: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	F1F	SEL	1C	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
13	20	2,030	2,018	3.3	1,710	1,700	22.6	2,085	19.9	13.0	2.1	25.6	17.5	1.0	10.2	10.7
14	28	3,200	3,100	7.1	2,750	2,659	24.9	3,321	15.7	10.8	1.8	29.2	18.8	0.2	8.9	14.6
15	29	3,870	3,805	0.8	3,500	3,441	11.5	3,835	19.5	13.4	1.9	29.2	17.3	0.4	8.1	10.2
16	37	5,555	5,361	2.4	5,020	4,831	13.6	5,487	18.4	10.5	1.9	28.1	16.2	1.3	7.5	16.1
17	46	8,045	7,870	2.9	7,240	7,047	14.9	8,098	19.8	12.0	1.8	28.8	15.5	0.4	8.3	13.4
18	26	5,260	5,183	2.5	4,860	4,782	11.1	5,314	19.7	11.0	1.2	33.4	14.8	0.5	8.3	11.1
19	34	7,755	7,549	-1.2	7,230	7,021	6.3	7,460	25.3	12.5	2.0	28.8	16.6	0.2	5.3	9.3
20	38	9,270	9,054	-1.0	9,010	8,793	1.9	8,959	23.8	12.4	2.2	34.9	11.6	1.0	6.7	7.4
21	22	6,335	6,160	0.7	6,020	5,827	6.5	6,204	26.0	10.3	1.9	33.3	13.3	2.5	7.1	5.6
22	13	4,220	4,060	-3.5	3,970	3,817	2.6	3,916	24.8	11.3	0.7	41.4	8.9	0.5	4.3	8.1
23	8	2,805	2,756	-2.3	2,740	2,693	0.0	2,692	28.5	17.8	4.2	27.2	9.5	0.4	6.4	6.0
24	7	2,465	2,371	-3.0	2,350	2,230	3.1	2,300	31.8	10.3	0.9	38.4	8.2	1.6	3.0	5.8
25	3	1,380	1,297	11.9	1,380	1,270	14.3	1,451	16.4	18.3	1.0	33.7	14.7	4.7	2.5	8.7
26	7	2,970	2,954	-1.8	2,960	2,941	-1.3	2,902	50.4	15.2	3.5	21.0	1.1	0.0	4.1	4.7
27	4	1,810	1,806	8.0	1,850	1,843	5.9	1,951	37.5	16.0	2.5	23.3	11.8	0.0	3.2	5.7
28	1	585	562	-6.6	580	548	-4.2	525	15.6	33.5	0.0	43.7	3.4	0.0	2.7	1.1
29	1	385	385	4.2	380	380	5.5	401	21.2	19.7	5.7	37.7	6.2	0.0	9.5	0.0
All diameters	324	67,940	66,291	0.9	63,550	61,823	8.2	66,901	24.0	12.5	1.9	31.1	13.5	0.8	6.7	9.5

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	SW	3A	3B
1/2	0.1	—	—	—	—	—	—	—
5/8	—	0.1	0.1	0.4	—	—	—	—
3/4	0.4	0.1	0.3	0.6	1.0	1.4	0.4	0.6
4/4	14.1	19.7	31.3	35.6	62.1	71.6	63.9	39.3
5/4	72.4	63.1	62.2	45.2	15.8	4.6	7.1	4.4
6/4	2.8	11.2	—	13.8	11.5	—	5.1	—
7/4	—	0.2	0.2	0.6	4.0	—	9.9	35.6
8/4	3.9	2.1	2.2	2.5	4.0	18.1	9.5	10.4
10/4	4.3	3.3	3.5	0.6	0.4	—	1.1	8.9
12/4	2.0	0.2	0.2	0.7	0.3	4.3	3.0	0.8
16/4	—	—	—	—	0.4	—	—	—
24/4	—	—	—	—	0.5	—	—	—
Total tally (board feet)	16,032	8,380	1,302	20,811	8,999	562	4,459	6,356

Table 20.—BLACK OAK: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	F1F	SEL	1C	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
10	6	340	340	7.1	280	280	30.0	364	—	1.6	6.0	22.3	41.8	—	22.8	5.5
11	29	1,765	1,704	8.6	1,400	1,351	36.9	1,850	2.0	6.6	3.0	14.8	23.6	2.4	22.5	25.1
12	57	4,475	4,288	3.6	3,800	3,622	22.7	4,443	2.8	4.7	1.4	21.0	24.9	2.1	16.1	27.0
13	38	3,700	3,602	0.8	3,130	3,048	19.1	3,631	1.9	4.7	0.6	23.3	26.3	1.5	17.8	23.9
14	55	5,705	5,477	6.5	4,950	4,737	23.1	5,832	3.4	3.9	0.8	23.9	20.6	1.3	13.3	32.8
15	72	9,515	9,248	0.8	8,590	8,342	11.8	9,324	4.6	5.6	1.3	25.6	22.2	1.3	10.9	28.5
16	56	8,535	8,183	0.3	7,700	7,358	11.5	8,205	4.2	4.5	1.5	24.9	23.3	0.9	12.6	28.1
17	46	7,830	7,514	2.5	7,080	6,786	13.5	7,699	5.5	4.4	1.4	31.2	25.0	1.2	9.7	21.6
18	35	6,520	6,384	-0.8	6,080	5,948	6.4	6,330	4.6	8.8	1.7	40.3	16.5	2.7	12.8	12.6
19	29	6,350	6,052	-3.0	5,940	5,638	4.1	5,871	8.3	7.2	1.4	35.4	21.3	2.0	9.8	14.6
20	10	2,345	2,190	1.5	2,310	2,145	3.6	2,223	6.2	4.3	1.1	30.4	21.6	1.0	12.0	23.4
21	10	2,995	2,973	-8.4	2,840	2,813	-3.2	2,723	9.9	9.0	0.6	33.8	20.0	1.2	10.8	14.7
22	4	1,135	1,128	-10.3	1,080	1,073	-5.7	1,012	17.2	13.4	0.8	28.7	16.6	5.5	13.5	4.3
23	2	575	480	-4.4	570	440	4.3	459	17.6	9.2	—	34.5	13.9	2.2	15.0	7.6
24	5	1,810	1,699	-4.9	1,730	1,608	0.5	1,616	6.0	7.3	1.9	40.4	26.1	—	11.6	6.7
25	2	800	783	-2.6	800	783	-2.6	763	14.5	16.5	—	37.9	16.4	—	10.5	4.2
26	3	1,240	1,223	-11.0	1,250	1,232	-11.6	1,089	10.0	7.6	0.6	40.7	27.7	0.1	7.7	5.6
27	1	540	540	-27.8	550	550	-29.1	390	9.5	6.9	1.8	73.9	7.9	—	—	—
28	1	355	355	-6.8	360	360	-8.1	331	1.8	7.3	—	68.6	16.9	—	5.4	—
All diameters	461	66,530	64,163	0.0	60,440	58,114	10.4	64,155	5.3	6.0	1.3	29.5	22.2	1.5	12.4	21.8

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	SW	3A	3B
1/2	—	—	—	—	0.1	—	—	—
5/8	—	0.2	0.2	0.4	—	—	—	—
3/4	—	—	—	0.6	0.6	1.8	1.0	0.4
4/4	22.2	24.0	24.9	39.4	55.6	80.4	62.9	32.6
5/4	75.0	68.3	67.9	48.3	19.6	10.0	6.0	6.9
6/4	2.1	4.1	—	8.2	12.8	—	2.7	—
7/4	—	—	—	0.3	4.2	—	9.8	13.5
8/4	0.7	1.7	5.1	2.3	4.6	7.8	15.5	12.5
10/4	—	—	—	0.5	—	—	1.8	3.3
12/4	—	1.7	1.9	—	0.7	—	0.3	0.8
16/4	—	—	—	—	0.8	—	—	—
24/4	—	—	—	—	1.0	—	—	—
Total tally (board feet)	3,427	3,836	836	18,940	14,235	969	7,949	13,963

Table 21.—BLACK OAK: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
8	15	445	438	4.1	320	315	44.8	456	—	—	—	2.2	15.4	4.8	25.7	51.9
9	28	1,100	1,083	2.6	920	916	21.3	1,111	—	—	0.2	7.2	21.7	11.6	31.8	27.5
10	50	2,430	2,358	2.3	1,980	1,924	25.4	2,413	0.2	—	—	6.2	19.6	7.7	31.2	35.1
11	30	1,755	1,700	1.9	1,410	1,364	27.1	1,733	—	0.6	1.0	10.7	21.0	10.0	31.3	25.4
12	42	3,060	2,963	-3.7	2,600	2,509	13.7	2,853	0.1	0.6	—	10.4	26.0	7.4	27.0	28.5
13	41	3,680	3,581	-1.2	3,100	3,015	17.3	3,537	0.1	1.1	—	11.6	29.2	9.7	21.8	26.5
14	37	3,720	3,599	-0.3	3,220	3,099	15.8	3,588	1.0	2.6	0.3	18.5	27.4	7.3	19.8	23.1
15	45	5,415	5,215	0.5	5,000	4,809	9.0	5,241	1.2	1.3	—	20.3	27.3	9.8	21.4	18.7
16	24	3,265	3,115	0.9	2,960	2,813	11.7	3,143	3.1	2.6	1.0	21.7	32.2	3.4	19.9	16.1
17	13	1,970	1,922	-2.2	1,790	1,747	7.6	1,879	—	3.1	0.3	23.6	39.0	7.7	17.1	9.2
18	9	1,680	1,638	1.3	1,580	1,540	7.8	1,660	—	3.2	0.3	36.4	31.3	3.2	17.5	8.1
19	7	1,600	1,536	-5.1	1,480	1,421	2.6	1,458	3.0	3.4	1.2	25.0	21.4	2.3	12.5	31.2
20	10	2,425	2,330	7.9	2,370	2,249	11.8	2,515	5.6	7.4	0.3	29.2	25.8	3.6	12.4	15.7
21	1	320	320	-10.0	300	300	-4.0	288	—	10.1	—	47.6	22.9	—	19.4	—
22	3	915	864	1.7	870	798	10.2	879	7.2	12.6	1.0	29.8	28.4	2.7	11.8	6.5
23	1	285	285	1.4	280	280	3.2	289	15.2	9.7	—	32.9	24.2	—	4.2	13.8
24	1	425	425	-8.5	400	400	-2.8	389	5.1	—	—	49.9	20.1	—	18.5	6.4
25	1	460	460	-0.7	460	460	-0.7	457	54.5	17.5	—	4.8	3.9	7.0	—	12.3
All diameters	358	34,950	33,832	0.2	31,040	29,959	13.1	33,889	2.3	2.7	0.3	18.9	26.6	6.9	21.0	21.3

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	SW	3A	3B
1 2	—	—	—	—	0.1	—	—	—
3/4	—	—	1.9	1.1	0.7	0.6	0.7	0.2
4/4	12.0	15.7	54.9	41.6	62.6	68.8	63.0	40.1
5/4	84.3	80.2	39.4	52.3	24.1	17.8	7.1	3.5
6/4	0.3	0.2	—	2.1	2.7	1.2	1.9	—
7 4	—	—	—	—	1.1	0.6	2.7	22.2
8 4	—	1.5	1.9	2.5	6.2	11.0	19.4	20.5
10 4	—	2.4	1.9	0.4	—	—	3.9	12.8
12 4	3.4	—	—	—	1.3	—	1.3	0.7
16 4	—	—	—	—	0.4	—	—	—
24 4	—	—	—	—	0.8	—	—	—
Total tally (board feet)	766	906	104	6,398	9,051	2,328	7,112	7,224

Table 22.—CHESTNUT OAK: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)											
		Int. 1 4-inch rule			Scribner Decimal C rule				FAS	FAS-WHND	F1F	F1F-WHND	SEL	SEL-WHND	1C	1C-WHND	2C	SW	3A	3B
		Gross	Net	Overrun	Gross	Net	Overrun													
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*											
13	13	1,240	1,192	-1.7	1,040	994	17.9	1,172	5.5	5.7	12.3	1.4	4.9	—	22.1	10.3	15.8	6.1	10.2	5.7
14	15	1,750	1,684	-3.2	1,480	1,414	15.3	1,630	6.7	11.0	6.7	1.7	3.5	—	21.1	12.3	13.0	9.2	10.6	4.2
15	13	1,615	1,490	-1.3	1,470	1,345	9.4	1,471	15.4	5.4	8.0	2.1	1.7	—	25.1	6.4	20.9	0.6	8.6	5.8
16	16	2,415	2,178	-4.7	2,180	1,930	7.6	2,076	8.0	7.8	8.8	3.1	1.9	0.2	19.7	10.4	14.7	5.1	10.7	9.6
17	17	2,930	2,744	-5.7	2,650	2,438	6.2	2,588	10.6	11.6	9.4	3.7	1.0	0.2	11.5	16.7	10.2	4.3	8.0	12.8
18	13	2,660	2,495	0.6	2,460	2,255	11.3	2,509	6.1	19.1	6.9	5.2	0.4	—	7.7	18.9	5.5	10.5	7.7	12.0
19	18	4,085	3,866	-0.4	3,810	3,578	7.6	3,851	4.5	25.1	5.6	4.4	0.8	0.8	10.8	17.2	6.3	6.6	8.7	9.2
20	13	2,845	2,636	-3.0	2,750	2,482	3.1	2,558	5.8	11.7	9.3	4.0	1.2	1.4	15.6	16.3	6.3	4.9	9.3	14.2
21	9	2,355	2,213	-9.1	2,270	2,098	-4.1	2,012	1.9	20.6	6.4	5.9	0.2	0.2	3.5	20.3	8.0	4.5	9.0	19.5
22	8	2,645	2,438	1.5	2,480	2,228	11.0	2,474	7.9	18.2	6.8	5.3	0.4	—	19.4	15.2	7.6	4.9	8.1	6.2
23	7	2,255	2,053	1.7	2,210	1,952	6.9	2,087	7.1	18.5	3.7	8.0	0.2	—	9.0	21.0	5.4	5.1	7.3	14.7
24	2	625	594	-18.0	600	561	-13.2	487	1.4	42.3	—	13.6	—	—	2.3	15.0	1.2	3.7	15.4	5.1
25	2	740	682	-1.2	740	674	—	674	2.8	6.1	2.8	4.7	—	0.9	2.1	44.4	6.5	4.2	9.9	15.6
26	3	1,205	1,181	-9.7	1,220	1,196	-10.9	1,066	17.7	11.1	8.3	1.7	—	—	12.5	13.2	9.8	7.4	5.7	12.6
27	1	540	486	-9.7	550	477	-8.0	439	10.3	11.4	6.4	7.1	—	—	19.4	12.8	18.5	—	11.4	2.7
28	1	585	585	-3.9	580	580	-3.1	562	4.3	8.0	—	—	—	—	37.2	33.8	1.6	1.2	10.7	3.2
29	1	630	630	1.6	610	610	4.9	640	—	1.6	—	1.4	—	—	19.4	10.6	28.1	11.1	23.3	4.5
30	2	990	931	19.7	980	921	21.0	1,114	9.9	4.4	9.5	—	—	—	21.5	25.5	7.5	7.5	5.7	8.5
All diameters	154	32,110	30,078	-2.2	30,080	27,733	6.0	29,410	7.1	14.6	6.9	4.1	1.0	0.3	14.4	16.9	9.5	5.8	9.1	10.3

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	FAS-WHND	F1F	F1F-WHND	SEL	SEL-WHND	1C	1C-WHND	2C	SW	3A	3B
1/2	—	—	0.2	—	—	—	—	—	—	0.2	0.1	—
5/8	—	—	—	—	—	—	0.1	—	0.2	—	—	0.1
3/4	1.1	0.3	—	—	—	—	0.3	0.2	2.3	1.1	3.7	2.3
4/4	26.1	14.0	22.7	16.5	56.8	92.8	39.6	44.1	86.6	57.4	90.1	94.5
5/4	21.5	15.9	21.1	10.8	29.1	—	17.8	20.7	5.0	18.7	0.9	1.2
6/4	51.3	69.8	56.0	71.9	14.1	7.2	41.9	35.0	5.9	22.6	5.2	1.9
7/4	—	—	—	0.8	—	—	0.3	—	—	—	—	—
Total tally (board feet)	2,096	4,298	2,039	1,207	296	83	4,237	4,963	2,782	1,695	2,674	3,040

Table 23.—CHESTNUT OAK: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)											
		Int. 1/4-inch rule			Scribner Decimal C rule															
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	FAS-WHND	F1F	F1F-WHND	SEL	SEL-WHND	1C	1C-WHND	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*											
10	10	560	524	-1.9	480	449	14.5	514	3.3	—	—	—	2.7	—	11.1	12.5	12.6	20.2	22.4	15.2
11	44	2,805	2,593	3.4	2,270	2,082	28.8	2,681	2.8	1.4	4.2	0.8	2.9	0.3	15.8	11.0	16.6	13.2	21.6	9.4
12	49	3,810	3,586	-3.8	3,240	3,044	13.3	3,448	1.2	3.3	3.9	0.7	3.8	0.3	13.8	9.8	16.9	15.3	18.2	12.8
13	45	4,085	3,766	-9.6	3,450	3,112	9.4	3,406	1.7	1.9	4.1	0.4	1.6	0.4	12.2	11.2	15.5	17.2	20.2	13.6
14	35	3,615	3,349	-3.8	3,120	2,865	12.4	3,221	1.4	3.8	2.5	1.8	0.4	0.6	11.0	15.1	11.6	14.4	17.5	19.9
15	40	4,935	4,679	-4.9	4,500	4,243	4.9	4,449	3.0	6.8	4.2	1.3	0.6	0.4	13.0	14.8	11.7	13.3	13.2	17.7
16	32	4,130	3,879	-6.1	3,760	3,515	3.6	3,643	1.9	4.0	2.7	4.2	0.6	0.5	6.3	18.8	8.6	15.3	16.5	20.6
17	22	3,650	3,347	-6.9	3,310	2,952	5.6	3,116	2.6	8.7	3.8	2.5	1.0	0.2	10.8	20.0	10.9	9.5	13.0	17.0
18	19	3,080	2,873	-3.4	2,910	2,685	3.3	2,774	3.4	7.3	2.5	4.0	0.5	0.4	10.1	27.9	9.4	8.2	16.0	10.3
19	21	3,970	3,647	-6.7	3,750	3,363	1.2	3,404	1.1	10.5	3.2	3.1	0.6	0.3	9.9	23.4	6.2	7.3	11.5	22.9
20	7	1,515	1,194	-7.6	1,490	1,100	0.3	1,103	—	8.3	—	2.7	0.4	0.4	4.5	28.0	4.0	7.6	11.2	32.9
21	6	1,670	1,571	-2.9	1,590	1,464	4.2	1,525	0.7	23.5	0.4	7.1	—	1.0	4.9	24.3	3.3	3.2	11.4	20.2
22	5	1,305	1,260	0.8	1,250	1,203	5.6	1,270	—	18.5	0.8	3.1	1.7	3.0	4.7	27.7	4.1	13.4	13.8	9.2
23	2	780	721	-12.9	760	687	-8.6	628	—	4.6	3.5	3.3	2.1	—	16.7	15.4	13.7	2.1	20.0	18.6
24	3	885	820	-5.7	860	782	-1.2	773	—	9.3	4.7	1.4	—	0.6	18.0	26.3	6.9	10.0	10.6	12.2
25	1	400	356	17.1	400	350	19.1	417	—	6.7	9.4	—	—	—	23.5	11.5	28.8	0.5	17.7	1.9
27	1	540	432	-3.0	550	416	0.7	419	—	9.8	—	8.6	—	—	—	51.8	—	5.0	8.6	16.2
28	2	1,015	959	-3.0	1,020	950	-2.1	930	1.3	6.0	17.1	—	—	—	23.9	26.9	2.7	2.8	10.5	8.8
All diameters	344	42,750	39,556	-4.6	38,710	35,262	7.0	37,721	1.8	6.7	3.5	2.3	1.2	0.5	11.2	18.4	10.8	11.7	15.6	16.3

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	FAS-WHND	F1F	F1F-WHND	SEL	SEL-WHND	1C	1C-WHND	2C	SW	3A	3B
1/2	—	—	—	—	—	—	0.1	—	—	—	0.1	0.1
5/8	—	—	—	—	—	—	0.4	0.3	—	—	0.1	—
3/4	—	0.5	0.4	0.6	1.1	—	0.5	0.6	1.2	1.2	2.6	2.8
4/4	44.6	31.7	36.8	26.9	58.2	65.7	60.5	58.9	89.3	76.5	93.9	93.5
5/4	38.7	23.8	20.3	38.6	29.5	11.4	20.4	22.5	7.3	16.5	2.2	2.4
6/4	16.7	44.0	42.5	33.9	11.2	22.9	18.1	17.7	2.2	5.8	1.1	1.2
Total tally (board feet)	675	2,528	1,322	867	447	175	4,238	6,941	4,072	4,399	5,889	6,168

Table 24.—CHESTNUT OAK: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)											
		Int. 1/4-inch rule			Scribner Decimal C rule															
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	FAS-WHND	F1F	F1F-WHND	SEL	SEL-WHND	1C	1C-WHND	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*											
8	19	470	453	-1.3	350	339	31.9	447	—	—	—	—	—	—	1.1	—	7.2	9.2	25.1	57.4
9	48	1,680	1,574	-4.8	1,460	1,369	9.5	1,499	—	—	—	—	—	—	2.1	2.1	7.3	18.0	27.6	42.9
10	78	3,690	3,489	-4.6	3,020	2,836	17.3	3,327	—	0.4	0.4	0.1	0.8	0.1	4.4	3.9	10.1	19.1	23.1	37.6
11	53	2,795	2,662	-2.7	2,290	2,176	19.0	2,590	—	1.2	0.3	0.6	1.4	0.2	3.0	5.5	11.1	21.9	21.7	33.1
12	35	2,425	2,366	-6.3	2,080	2,024	9.5	2,216	—	2.6	—	0.5	0.2	0.1	3.9	11.6	8.5	18.5	20.8	33.3
13	30	2,515	2,392	-9.2	2,160	2,048	6.0	2,171	—	1.3	0.7	1.7	0.4	—	6.9	10.3	9.8	26.5	22.8	19.6
14	26	2,750	2,613	-12.7	2,370	2,248	1.5	2,282	1.9	1.6	0.4	1.4	—	—	6.4	10.6	10.9	25.2	17.7	23.9
15	14	1,610	1,508	-8.1	1,480	1,374	0.9	1,386	0.6	1.1	0.5	—	—	—	4.5	15.7	5.3	28.2	14.6	29.5
16	12	1,565	1,462	-13.3	1,420	1,313	-3.4	1,268	—	5.9	1.2	3.0	0.3	0.2	10.6	14.9	7.6	13.1	15.5	27.7
17	10	1,370	1,292	-7.5	1,260	1,171	2.0	1,195	—	3.7	—	2.4	0.5	0.3	4.7	14.7	4.6	22.4	8.2	38.5
18	10	1,625	1,539	-8.2	1,530	1,435	-1.5	1,413	—	1.5	—	0.4	—	—	3.4	21.4	3.5	18.6	20.1	31.1
19	6	1,250	1,216	-8.5	1,170	1,134	-1.9	1,113	—	2.4	—	—	—	—	2.2	29.8	7.5	14.8	16.1	27.2
20	4	655	631	2.2	660	632	2.1	645	—	3.6	2.3	1.9	—	—	13.3	10.1	6.2	20.6	16.0	26.0
21	1	235	218	-7.3	230	207	-2.4	202	—	7.4	—	—	—	—	—	27.7	6.9	10.9	18.8	28.3
22	3	695	621	-15.9	670	561	-7.0	522	—	1.9	5.4	—	—	—	10.0	28.2	12.6	12.6	5.9	23.4
23	1	335	322	-9.0	330	317	-7.6	293	—	22.9	—	—	—	—	6.5	12.3	4.1	39.9	—	14.3
24	1	310	295	-22.0	300	285	-19.3	230	—	19.6	—	8.3	—	—	—	31.7	3.5	3.9	1.7	31.3
25	1	460	396	-8.8	460	376	-4.0	361	—	50.7	—	3.9	—	—	—	24.9	—	—	2.5	18.0
26	1	500	451	-19.3	500	460	-20.9	364	—	24.5	—	2.5	—	—	—	45.2	—	6.9	—	20.9
All diameters	353	26,935	25,500	-7.7	23,740	22,305	5.5	23,524	0.2	3.3	0.5	1.0	0.4	0.1	4.8	12.2	8.1	20.0	18.5	30.9

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	FAS-WHND	F1F	F1F-WHND	SEL	SEL-WHND	1C	1C-WHND	2C	SW	3A	3B
1 2	—	—	—	—	—	—	—	—	0.5	—	—	—
3 4	—	—	—	—	—	—	0.7	0.8	0.3	1.8	2.9	2.1
4 4	100.0	66.4	45.4	60.4	81.2	100.0	66.8	71.5	96.5	87.5	95.5	96.0
5 4	—	14.5	7.4	21.8	18.8	—	16.4	17.9	2.7	7.8	1.6	1.7
6 4	—	19.1	47.2	17.8	—	—	16.1	9.8	—	2.9	—	0.2
Total tally (board feet)	51	780	108	225	85	19	1,122	2,874	1,911	4,706	4,359	7,284

Table 25.—NORTHERN RED OAK: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale: Int. 1/4-inch rule Gross	Int. 1/4-inch rule Net	Int. 1/4-inch rule Overrun	Scribner Decimal C rule Gross	Scribner Decimal C rule Net	Scribner Decimal C rule Overrun	Total lumber tally	NHLA lumber grade yields (actual): FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		Percent	Board feet		Percent	Board feet	Percent						
13	15	1,350	1,239	14.5	1,120	1,002	41.6	1,419	18.5	16.5	5.1	21.4	22.6	15.0	0.9
14	26	2,980	2,793	7.6	2,540	2,340	28.5	3,006	24.7	15.0	3.3	27.7	17.8	9.4	2.1
15	26	3,250	3,331	4.8	3,160	2,961	17.9	3,491	25.2	15.0	3.5	24.5	21.9	8.0	1.9
16	43	6,445	6,121	4.3	5,820	5,466	16.8	6,382	24.7	12.6	3.3	27.4	22.2	8.8	1.0
17	42	7,785	7,350	11.9	6,950	6,449	27.6	8,227	32.1	14.8	3.7	26.1	16.7	5.5	1.1
18	38	7,330	6,961	8.7	6,840	6,413	18.0	7,570	28.7	16.1	2.5	27.3	15.4	8.3	1.7
19	44	10,145	9,806	7.9	9,440	9,111	16.2	10,585	37.9	13.3	2.8	23.6	15.4	5.3	1.7
20	35	8,200	7,919	6.8	7,980	7,669	10.3	8,461	33.8	15.0	1.7	28.6	13.5	5.9	1.5
21	29	7,700	7,266	7.7	7,370	6,772	15.6	7,829	30.9	13.6	1.4	33.0	13.8	4.8	2.5
22	36	10,670	10,151	3.5	10,100	9,469	11.0	10,507	33.0	16.4	1.7	25.2	15.4	5.2	3.1
23	26	8,485	8,297	6.4	8,310	8,062	9.5	8,828	34.6	15.4	3.2	26.4	12.9	5.1	2.4
24	20	7,765	7,088	9.5	7,350	6,486	19.6	7,760	30.9	13.6	3.5	31.7	10.2	7.3	2.8
25	15	6,180	6,001	0.7	6,190	5,966	1.3	6,042	40.7	12.3	4.0	26.4	8.8	5.3	2.5
26	12	5,220	4,832	6.9	5,250	4,742	8.9	5,165	25.8	10.5	4.2	38.0	14.2	4.9	2.4
27	3	1,480	1,375	6.0	1,510	1,381	5.5	1,457	24.1	9.6	7.9	40.5	11.8	6.1	—
28	5	2,390	2,277	9.4	2,390	2,236	11.4	2,491	40.1	12.4	1.4	30.8	11.2	3.5	0.6
29	3	1,395	1,279	14.8	1,370	1,255	17.0	1,468	26.9	18.9	—	38.4	8.4	5.2	2.2
30	1	495	485	15.1	490	476	17.2	558	22.9	9.3	7.5	50.3	5.2	4.8	—
31	1	530	530	12.5	530	530	12.5	596	56.1	11.2	5.0	20.1	5.4	2.2	—
All diameters	420	100,065	95,101	7.1	94,710	88,786	14.7	101,842	31.9	14.2	2.9	28.3	14.6	6.1	2.0

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
3/8	—	—	—	—	—	—	—
1/2	—	—	—	—	—	0.1	—
5/8	0.1	—	—	0.1	0.1	0.2	0.2
3/4	0.4	0.4	0.1	0.7	1.5	2.2	2.0
4/4	23.0	33.5	40.9	48.1	82.4	92.6	93.5
5/4	65.3	60.9	58.6	49.3	15.6	4.6	3.3
6/4	11.2	5.2	0.4	1.8	0.4	0.3	1.0
Total tally (board feet)	32,511	14,459	2,965	28,771	14,870	6,268	1,998

Table 26.—NORTHERN RED OAK: log grade 2: dry lumber grade yield, by scaling diameter

Table 26.—NORTHERN RED OAK: log grade 2: dry lumber grade yield, by scaling

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
10	9	435	422	6.4	340	326	37.7	449	2.4	6.9	5.1	32.8	26.5	23.6	2.7
11	44	2,590	2,390	10.8	2,030	1,870	41.7	2,649	5.1	5.8	4.8	20.3	33.4	22.5	8.1
12	60	4,415	4,172	6.6	3,750	3,525	26.2	4,437	6.4	6.9	2.8	25.0	34.1	18.9	5.9
13	66	5,875	5,449	3.2	4,940	4,519	24.5	5,626	4.7	5.2	2.9	31.6	31.3	17.4	6.9
14	57	5,710	5,336	5.2	4,970	4,576	22.7	5,608	9.2	8.4	3.2	30.4	28.5	17.2	3.1
15	72	8,505	7,925	2.3	7,770	7,137	13.6	8,108	11.7	7.5	2.3	29.6	29.5	14.9	4.5
16	50	7,205	6,896	0.1	6,520	6,218	11.0	6,904	9.8	11.2	2.9	34.1	26.7	10.9	4.4
17	41	6,375	5,988	3.9	5,820	5,410	15.0	6,220	12.3	8.0	1.6	36.9	22.5	12.4	6.3
18	35	5,995	5,425	4.5	5,630	4,972	14.1	5,671	16.6	10.7	2.8	30.4	22.5	12.3	4.7
19	33	6,010	5,615	1.7	5,700	5,228	9.2	5,710	11.9	6.9	2.5	39.5	23.6	10.2	5.4
20	16	3,165	2,965	-2.1	3,110	2,862	1.4	2,903	10.7	11.7	1.2	32.5	21.7	11.6	10.6
21	15	3,450	3,176	3.2	3,340	2,982	9.9	3,278	7.6	8.3	1.4	50.0	16.9	9.3	6.5
22	14	3,880	3,486	3.6	3,700	3,237	11.6	3,611	14.5	10.2	1.7	38.4	22.1	9.0	4.1
23	6	1,920	1,800	-2.9	1,890	1,740	0.4	1,747	9.2	11.6	0.2	46.1	12.5	11.3	9.1
24	7	2,110	1,800	8.4	2,050	1,636	19.3	1,951	23.5	14.8	4.2	36.1	15.8	3.2	2.4
25	5	1,670	1,612	4.0	1,700	1,624	3.2	1,676	22.1	15.2	0.4	39.0	20.0	3.3	—
26	2	805	783	13.9	810	780	14.4	892	1.3	7.5	—	67.7	15.1	6.4	2.0
29	3	1,805	1,444	-9.3	1,750	1,300	0.8	1,310	9.5	7.5	—	53.3	20.5	7.7	1.5
30	1	410	213	7.0	410	164	39.0	228	20.6	15.4	3.5	36.4	19.7	3.1	1.3
All diameters	536	72,330	66,897	3.1	66,230	60,106	14.8	68,978	10.8	8.8	2.4	34.5	25.3	13.0	5.2

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1/2	—	—	—	—	—	0.2	0.1
5/8	0.1	—	—	0.1	0.1	0.1	0.3
3/4	0.3	0.7	0.3	1.0	1.2	1.6	1.9
4/4	39.3	45.9	71.4	64.1	87.7	93.6	93.1
5/4	47.4	46.2	27.7	33.3	10.7	4.0	2.4
6/4	12.9	7.2	0.6	1.5	0.2	—	—
8/4	—	—	-	—	0.1	0.5	2.2
Total tally (board feet)	7,477	6,063	1,648	23,829	17,424	8,943	3,594

Table 27.—NORTHERN RED OAK: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1 4-inch rule			Scribner Decimal C rule										
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
8	24	620	583	11.0	490	459	41.0	647	—	—	3.1	4.9	27.7	42.0	22.3
9	40	1,400	1,276	16.1	1,200	1,090	36.0	1,482	—	—	1.0	1.6	12.6	35.8	36.4	12.6
10	49	2,085	1,870	9.6	1,670	1,475	38.9	2,049	1.4	0.5	1.1	8.8	38.0	37.4	12.8
11	52	2,590	2,348	9.6	2,160	1,939	32.7	2,574	0.6	1.2	1.2	14.3	40.3	31.7	10.7
12	36	2,370	2,213	0.9	2,030	1,879	18.8	2,232	0.3	1.2	1.1	14.9	34.7	35.1	12.7
13	40	3,030	2,729	0.3	2,590	2,302	18.9	2,738	1.2	3.0	0.8	22.7	35.1	25.3	11.9
14	28	2,650	2,419	2.9	2,330	2,103	18.3	2,488	1.0	1.6	1.3	21.4	37.5	21.5	15.7
15	25	2,630	2,515	-4.8	2,410	2,297	4.2	2,394	—	3.4	0.8	27.6	34.4	23.7	10.1
16	23	3,255	3,112	1.6	2,950	2,815	12.4	3,163	3.5	6.0	1.1	27.4	31.9	18.4	11.7
17	10	1,550	1,377	3.1	1,410	1,213	17.1	1,420	9.4	8.4	1.5	29.6	34.8	9.8	6.5
18	8	1,330	1,226	-6.4	1,250	1,116	2.8	1,147	5.1	4.9	—	25.3	32.0	13.3	19.4
19	5	1,020	904	-5.5	960	810	5.4	854	10.9	4.3	—	19.8	35.3	22.4	7.3
20	7	1,675	1,572	-12.2	1,640	1,519	-9.1	1,381	5.8	3.6	1.6	28.9	29.5	16.4	14.2
21	5	1,350	1,277	-7.5	1,290	1,198	-1.4	1,181	1.2	2.8	—	35.5	30.3	13.4	16.8
22	1	305	204	13.7	290	166	39.8	232	—	—	—	12.5	31.9	48.3	7.3
23	2	595	589	-12.1	590	582	-11.0	518	—	5.4	—	40.3	38.8	11.6	3.9
24	1	310	282	-45.7	300	262	-41.6	153	—	—	2.0	27.5	32.5	19.0	19.0
25	1	250	242	9.9	260	252	5.6	266	10.2	9.8	--	52.6	21.4	6.0	—
26	1	240	211	-4.3	250	212	-4.7	202	5.4	4.0	—	38.6	33.2	7.4	11.4
27	1	470	461	-18.7	480	464	-19.2	375	—	18.4	—	39.7	25.9	8.5	7.5
28	1	355	227	20.7	360	230	19.1	274	34.6	13.9	5.5	24.8	10.6	9.1	1.5
All diameters	360	30,080	27,637	0.5	26,910	24,383	13.9	27,770	2.6	3.4	1.0	22.3	34.4	24.2	12.1

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1/2	—	—	—	—	—	—	—
5/8	—	—	—	0.1	—	0.1	0.1
3/4	—	0.4	—	0.9	0.8	2.3	2.6
4/4	36.1	49.1	76.9	79.1	92.2	94.3	90.6
5/4	58.3	49.7	23.1	19.4	6.1	2.2	2.5
6/4	5.6	0.8	—	0.5	0.1	—	0.5
8/4	—	—	—	—	0.8	1.1	3.7
Total tally (board feet)	731	943	290	6,196	9,530	6,712	3,368

Table 28.—SCARLET OAK: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
13	2	170	170	11.2	140	140	35.0	189	21.2	10.6	3.2	15.9	32.2	16.9	—
14	2	270	270	-9.6	220	220	10.9	244	11.5	7.4	19.7	29.4	7.4	6.6	18.0
15	1	135	135	-8.9	120	120	2.5	123	17.1	37.4	—	18.7	19.5	7.3	—
16	7	1,210	1,179	11.2	1,080	1,053	24.5	1,311	14.8	6.3	—	38.3	19.8	15.1	5.7
17	15	2,970	2,764	2.9	2,620	2,437	16.7	2,844	11.6	5.9	1.2	42.6	18.3	15.3	5.1
18	5	1,030	938	8.7	960	874	16.7	1,020	24.9	9.9	1.6	35.8	9.7	13.3	4.8
19	4	900	877	-0.3	840	818	6.8	874	13.4	7.1	3.0	40.7	16.6	13.3	5.9
20	4	1,160	1,033	13.3	1,120	997	17.4	1,170	31.1	9.9	1.1	37.0	11.0	4.9	5.0
21	4	1,200	1,181	-1.2	1,140	1,123	3.9	1,167	22.5	12.4	3.7	36.3	12.1	9.5	3.5
22	1	305	281	-2.5	290	267	2.6	274	—	4.7	—	30.7	34.3	7.7	22.6
23	2	725	675	4.9	710	660	7.3	708	20.3	13.0	1.3	31.6	16.4	9.9	7.5
All diameters	47	10,075	9,503	4.4	9,240	8,709	14.0	9,924	17.7	8.7	2.0	37.5	16.2	12.1	5.8

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1/2	0.3	0.5	—	0.9	0.2	0.5	—
5/8	47.1	43.1	43.3	50.6	11.7	0.6	—
3/4	—	—	—	0.4	1.4	0.6	2.1
4/4	27.3	33.4	31.4	35.5	82.0	95.3	97.9
5/4	25.3	23.0	25.3	12.6	4.7	—	—
8/4	—	—	—	—	—	3.0	—
Total tally (board feet)	1,756	865	194	3,721	1,607	1,202	579

Table 29.—SCARLET OAK: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
11	9	590	571	5.6	450	435	38.6	603	3.0	4.3	4.5	26.2	22.2	25.2	14.6
12	17	1,360	1,323	9.8	1,150	1,116	30.1	1,452	2.4	2.5	1.6	25.8	31.1	23.1	13.5
13	16	1,705	1,635	1.6	1,440	1,382	20.2	1,661	3.0	3.9	2.7	21.2	27.2	28.0	14.0
14	15	1,700	1,639	4.6	1,440	1,387	23.6	1,714	4.1	2.5	0.9	25.2	25.6	25.5	16.2
15	20	2,815	2,697	1.4	2,520	2,415	13.3	2,736	3.7	3.4	1.8	33.7	28.3	14.0	15.1
16	14	2,300	2,234	4.2	2,060	2,001	16.3	2,327	2.8	4.0	0.9	31.8	31.8	21.1	7.6
17	12	2,195	2,101	-6.3	1,960	1,876	5.0	1,969	6.1	6.9	0.8	29.0	29.2	18.2	9.8
18	8	1,420	1,301	6.4	1,340	1,227	12.8	1,384	8.0	7.4	0.8	35.6	24.7	16.7	6.8
19	8	1,940	1,616	4.1	1,800	1,499	12.3	1,683	3.0	6.0	0.8	32.7	29.1	18.3	10.1
20	2	540	452	-3.5	520	436	—	436	6.0	13.1	—	29.3	21.3	10.6	19.7
21	1	280	255	-4.3	270	246	-0.8	244	—	—	—	14.3	45.5	25.4	14.8
22	2	615	615	-5.7	580	580	—	580	1.7	2.8	—	20.9	25.8	24.1	24.7
23	1	390	390	10.5	380	380	13.4	431	—	—	—	17.6	41.3	38.5	2.6
All diameters	125	17,850	16,829	2.3	15,910	14,980	15.0	17,220	3.8	4.5	1.3	28.7	28.6	20.8	12.3

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1 2	—	0.8	—	0.1	0.3	0.2	0.2
5 8	36.7	34.9	21.3	46.8	12.4	2.7	1.2
3 4	—	—	—	0.5	1.0	0.4	0.9
4 4	25.6	34.6	64.2	39.9	79.8	88.8	79.4
5 4	37.7	29.7	14.5	12.7	3.1	—	0.3
8 4	—	—	—	—	1.1	6.6	16.3
12 4	—	—	—	—	2.3	1.3	1.7
Total tally (board feet)	656	768	221	4,956	4,923	3,578	2,118

Table 30.—SCARLET OAK: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
8	4	85	84	23.8	80	79	31.6	104	—	—	—	2.9	15.4	29.8	51.9
9	11	370	353	10.5	320	305	27.9	390	—	1.5	1.0	2.1	1.5	34.1	59.8
10	34	1,620	1,532	16.4	1,330	1,253	42.3	1,783	—	0.4	0.3	5.1	14.9	37.8	41.5
11	32	2,055	1,962	13.0	1,670	1,589	39.5	2,217	—	0.5	—	7.2	24.9	35.0	32.4
12	34	2,385	2,285	8.7	2,040	1,957	26.9	2,483	—	—	0.6	4.9	24.3	40.4	29.8
13	27	2,315	2,207	5.5	1,980	1,885	23.5	2,328	—	0.6	0.5	14.5	22.5	38.7	23.2
14	29	3,230	3,107	4.7	2,730	2,626	23.8	3,252	0.4	1.6	0.4	14.3	35.0	33.8	14.5
15	27	3,315	3,236	1.4	3,020	2,947	11.4	3,282	0.8	0.7	—	15.7	35.2	31.5	16.1
16	9	1,285	1,236	3.6	1,160	1,106	15.7	1,280	0.3	—	—	15.5	39.2	28.0	17.0
17	5	840	809	4.9	750	722	17.6	849	0.7	2.8	—	22.6	45.0	21.1	7.8
18	4	680	605	6.3	630	561	14.6	643	—	—	—	16.8	29.5	38.8	14.9
19	3	560	520	0.2	540	497	4.8	521	—	—	—	23.2	36.9	18.8	21.1
20	4	770	726	-5.8	770	725	-5.7	684	8.3	0.7	—	27.0	44.3	10.1	9.6
All diameters	223	19,510	18,662	6.2	17,020	16,252	21.9	19,816	0.5	0.7	0.3	12.6	29.4	33.4	23.1

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	3A	3B
1/2	—	—	—	0.3	—	0.2	0.1
5/8	39.3	49.0	8.0	41.3	10.2	1.9	0.9
3/4	—	—	—	0.4	0.6	1.0	0.5
4/4	60.7	51.0	92.0	55.7	83.4	89.1	93.6
5/4	—	—	—	2.3	0.4	0.6	0.2
8/4	—	—	—	—	5.1	5.7	4.7
12/4	—	—	—	—	0.3	1.5	—
Total tally (board feet)	107	145	50	2,506	5,828	6,602	4,578

Table 31.—WHITE OAK: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale: Int. 1/4-inch rule Gross	Int. 1/4-inch rule Net	Int. 1/4-inch rule Overrun	Scribner Decimal C rule Gross	Scribner Decimal C rule Net	Scribner Decimal C rule Overrun	Total lumber tally	NHLA lumber grade yields (actual): FAS	F1F	SEL	1C	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
13	13	1,260	1,236	-2.0	1,070	1,041	16.3	1,211	13.0	13.3	3.4	30.2	16.1	3.2	14.0	6.8
14	10	1,035	1,010	2.5	900	869	19.1	1,035	21.3	16.9	5.6	21.9	18.3	—	12.6	3.4
15	23	3,110	2,972	4.0	2,810	2,654	16.4	3,090	15.3	11.9	3.3	25.2	20.8	4.8	12.6	6.1
16	21	3,415	3,314	-2.9	3,060	2,932	9.8	3,218	22.4	13.5	3.5	28.3	17.0	2.1	7.5	5.7
17	11	1,960	1,920	0.7	1,760	1,722	12.3	1,933	18.8	10.7	7.1	22.2	21.0	7.1	9.4	3.7
18	13	2,690	2,565	-10.0	2,480	2,322	-0.6	2,309	13.7	8.5	2.8	21.8	20.6	8.8	13.9	9.9
19	16	3,460	3,350	2.0	3,240	3,102	10.2	3,417	15.4	9.2	3.3	36.5	21.1	5.3	7.1	2.1
20	10	2,115	2,028	2.3	2,080	1,968	5.4	2,074	20.2	13.5	4.2	25.5	20.0	1.4	8.5	6.7
21	10	3,035	2,964	3.7	2,590	2,495	23.2	3,074	16.8	15.1	5.8	28.2	15.2	3.2	9.5	6.2
22	9	2,760	2,633	0.1	2,610	2,453	7.5	2,636	14.2	19.4	3.2	40.3	16.8	—	4.4	1.7
23	8	2,435	2,377	1.0	2,390	2,320	3.5	2,401	17.0	9.0	4.6	29.0	24.9	8.9	4.4	2.2
24	8	3,000	2,847	10.7	2,850	2,673	17.9	3,152	13.1	16.6	0.9	41.1	19.2	1.0	5.3	2.8
26	2	870	850	1.4	870	845	2.0	862	19.0	11.4	3.1	35.1	14.8	—	13.5	3.1
27	1	540	524	9.2	550	534	7.1	572	22.7	2.3	3.1	57.7	14.2	—	-	—
28	1	585	585	-8.5	580	580	-7.8	535	7.3	29.0	—	43.6	7.1	2.2	2.6	8.2
29	1	630	630	-22.9	610	610	-20.3	486	39.4	7.2	7.8	36.0	4.9	—	1.6	3.1
All diameters	157	32,900	31,805	0.6	30,450	29,120	9.9	32,005	17.0	13.0	3.7	31.1	18.7	3.6	8.3	4.6

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	SW	3A	3B
3/8	—	—	—	0.1	—	—	—	—
1/2	0.1	—	0.2	0.1	—	—	—	—
5/8	—	—	—	—	0.1	—	0.1	—
3/4	0.3	0.8	—	1.4	2.4	2.5	4.4	3.2
1/4	24.1	21.7	45.9	39.6	69.0	71.8	83.8	85.1
5/4	56.2	41.7	28.9	37.2	22.7	16.1	7.5	3.3
6/4	19.3	35.8	25.0	21.5	5.4	9.6	—	—
8/4	—	—	—	0.1	0.4	—	4.2	8.4
Total tally (board feet)	5,132	4,148	1,200	9,954	5,978	1,165	2,669	1,459

Table 32.—WHITE OAK: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
10	4	230	227	-11.5	180	178	12.9	201	—	—	4.5	9.5	41.2	—	24.4	20.4
11	31	1,980	1,895	-8.0	1,610	1,533	13.7	1,743	1.5	4.2	4.2	13.5	27.3	6.4	22.0	20.9
12	44	3,145	3,083	-1.5	2,700	2,643	14.9	3,036	1.1	6.2	1.3	19.4	28.6	10.6	18.1	14.7
13	46	4,260	4,138	-9.6	3,590	3,474	7.6	3,739	2.3	4.4	1.1	17.7	29.9	9.6	21.5	13.5
14	48	5,060	4,975	-11.6	4,370	4,272	2.9	4,398	3.4	4.2	1.2	22.1	30.3	7.7	20.8	10.3
15	41	5,395	5,215	-6.6	4,860	4,669	4.3	4,869	3.8	4.4	3.5	26.0	32.5	4.2	15.1	10.5
16	36	4,985	4,814	-6.6	4,530	4,348	3.4	4,495	6.8	7.9	2.2	27.1	28.5	6.4	13.0	8.1
17	29	4,700	4,597	-3.3	4,280	4,183	6.2	4,444	6.4	5.0	1.8	31.0	28.0	5.7	11.3	10.8
18	23	4,210	4,044	0.2	3,940	3,735	8.5	4,053	5.1	3.8	2.7	34.0	25.3	9.5	12.2	7.4
19	14	2,905	2,839	0.2	2,730	2,657	7.1	2,845	9.6	4.2	2.0	32.9	28.4	5.2	12.4	5.3
20	7	1,635	1,609	-6.3	1,600	1,567	-3.8	1,507	7.2	4.7	1.4	43.0	26.7	2.1	8.7	6.2
21	8	2,270	2,070	-1.8	2,160	1,945	4.5	2,033	5.6	9.0	2.7	36.7	28.8	3.1	8.3	5.8
22	9	2,595	2,501	1.9	2,470	2,352	8.4	2,549	8.2	6.3	1.8	34.5	20.5	9.0	14.3	5.4
23	3	805	784	-6.3	790	762	-3.5	735	1.1	3.3	1.0	37.3	39.1	9.5	8.7	—
24	1	425	408	-2.2	400	379	5.3	399	6.8	7.8	—	33.8	39.0	3.3	3.3	6.0
25	3	1,080	1,068	-9.5	1,090	1,078	-10.3	967	3.4	6.9	—	42.8	23.3	—	15.3	8.3
All diameters	347	45,680	44,267	-5.1	41,300	39,775	5.6	42,013	4.9	5.3	2.0	27.9	28.6	6.7	14.9	9.7

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	SW	3A	3B
3/8	0.1	0.1	—	—	0.1	—	—	0.1
1/2	—	0.2	—	0.1	0.1	—	0.1	0.1
5/8	—	—	—	0.3	0.1	—	0.3	0.1
3/4	0.9	1.0	0.9	1.7	2.3	2.5	2.7	5.1
4/4	44.3	39.4	45.5	54.2	76.9	77.7	86.6	78.0
5/4	43.6	47.5	46.4	36.5	16.1	13.2	3.7	1.8
6/4	11.1	11.8	7.2	7.0	2.6	2.1	0.4	—
7/4	—	—	—	0.2	0.2	—	0.4	1.3
8/4	—	—	—	—	1.6	4.5	5.6	13.5
12/4	—	—	—	—	—	—	0.2	—
Total tally (board feet)	2,049	2,218	857	11,748	12,002	2,820	6,253	4,066

Table 33.—WHITE OAK: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	F1F	SEL	1C	2C	SW	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
8	29	815	793	-13.0	600	582	18.6	690	—	—	—	1.7	7.4	2.3	25.1	63.5
9	42	1,660	1,607	-7.7	1,360	1,314	12.9	1,483	0.3	1.6	0.2	2.2	16.8	1.6	24.6	52.7
10	59	2,920	2,841	-4.4	2,410	2,343	15.9	2,715	—	0.6	0.9	4.7	20.4	7.1	27.5	38.8
11	44	2,700	2,637	-11.2	2,140	2,092	12.0	2,342	—	—	0.3	5.9	26.3	13.5	29.2	24.8
12	58	4,165	4,068	-8.3	3,570	3,473	7.4	3,731	0.8	1.1	0.1	7.9	28.9	8.7	29.7	22.8
13	41	3,625	3,494	-6.1	3,050	2,932	11.9	3,280	0.7	0.5	0.2	8.8	32.0	11.6	22.5	23.7
14	47	4,775	4,620	-7.4	4,120	3,966	7.9	4,279	1.3	1.6	0.8	13.1	32.2	11.4	22.0	17.6
15	37	4,560	4,439	-4.2	4,170	4,047	5.1	4,252	0.7	1.9	0.1	18.3	35.3	12.3	18.3	13.1
16	25	3,505	3,371	-0.2	3,170	3,008	11.8	3,363	1.0	0.9	1.6	17.0	38.3	10.5	17.0	13.7
17	26	3,780	3,634	-3.7	3,470	3,318	5.5	3,500	1.0	2.9	1.3	19.7	29.4	17.7	16.7	11.3
18	22	3,710	3,495	-3.9	3,500	3,243	3.6	3,359	0.7	1.5	—	31.0	33.0	8.6	15.4	9.8
19	13	2,435	2,341	-0.1	2,290	2,190	6.8	2,339	4.1	5.5	0.3	29.7	20.4	10.3	14.5	15.2
20	12	2,770	2,487	-5.4	2,720	2,362	-0.4	2,352	1.6	3.8	—	25.5	32.3	11.1	14.7	11.0
21	7	1,990	1,962	-1.7	1,910	1,874	2.9	1,929	3.6	7.2	0.8	42.3	29.9	11.9	4.3	—
22	2	525	498	-8.2	500	466	-1.9	457	3.1	7.9	—	28.2	29.5	10.7	17.5	3.1
23	1	335	204	-22.5	330	158	—	158	—	—	—	5.1	5.1	—	55.0	34.8
24	2	680	582	3.8	650	521	15.9	604	—	6.6	—	38.5	32.8	2.0	13.1	7.0
All diameters	467	44,950	43,073	-5.2	39,960	37,889	7.8	40,833	1.1	2.1	0.5	17.2	29.5	10.6	20.1	18.9

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	F1F	SEL	1C	2C	SW	3A	3B
3/8	—	—	—	—	0.1	—	0.1	—
1/2	—	—	—	0.2	—	—	—	0.1
5/8	—	—	—	0.4	0.3	—	0.1	0.2
3/4	—	0.6	—	1.7	2.1	1.2	3.7	3.1
4/4	33.8	54.5	69.9	65.6	82.0	70.3	82.7	80.4
5/4	50.1	22.8	25.2	29.1	10.7	8.2	2.4	1.8
6/4	16.1	22.1	4.9	2.7	0.3	0.7	0.2	0.1
7/4	—	—	—	—	0.2	3.2	1.0	1.9
8/4	-	—	—	0.3	3.6	15.7	9.0	12.2
9/4	—	—	—	—	0.5	0.7	0.4	—
12/4	—	—	—	—	0.2	—	0.4	0.2
Total tally (board feet)	453	861	206	7,018	12,046	4,321	8,227	7,701

Table 34.—YELLOW POPLAR: log grade 1: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	SEL	SAP	1C	2A	2B	3C
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
13	16	1,630	1,576	-1.1	1,380	1,326	17.6	1,559	0.8	5.5	8.1	35.9	26.3	15.8	7.6
14	27	3,140	3,059	-4.7	2,670	2,582	12.9	2,914	2.8	6.5	11.5	39.0	31.9	5.8	2.5
15	20	2,965	2,845	-9.2	2,630	2,501	3.3	2,583	3.1	8.3	5.6	39.3	34.4	6.5	2.8
16	25	3,720	3,592	-4.6	3,360	3,221	6.4	3,426	6.0	7.2	11.2	38.5	25.2	7.6	4.3
17	36	6,765	6,508	-3.0	6,020	5,731	10.2	6,314	6.4	8.5	4.4	41.3	26.9	7.2	5.3
18	23	4,660	4,450	-4.9	4,320	4,084	3.6	4,233	3.7	9.5	10.3	37.8	28.2	6.9	3.6
19	22	4,985	4,626	-3.6	4,650	4,241	5.2	4,461	6.3	11.8	5.6	42.9	23.4	5.9	4.1
20	12	2,890	2,799	-1.8	2,820	2,703	1.7	2,749	7.6	14.0	8.0	43.9	17.7	6.8	2.0
21	18	5,090	5,010	-7.3	4,830	4,740	-2.0	4,645	11.4	10.3	4.0	41.8	18.8	11.2	2.5
22	13	3,670	3,626	-4.0	3,490	3,450	0.9	3,481	6.4	3.4	7.8	44.4	28.8	6.4	2.8
23	6	1,865	1,847	-8.4	1,830	1,810	-6.6	1,691	11.1	8.6	2.4	46.9	20.3	2.8	7.9
24	5	1,555	1,503	-2.1	1,500	1,450	1.4	1,471	7.8	8.1	5.9	36.8	35.6	3.3	2.5
25	3	1,140	1,130	4.4	1,140	1,130	4.4	1,180	18.8	3.7	11.5	52.1	11.2	0.6	2.1
26	6	2,285	2,250	-13.9	2,290	2,255	-14.1	1,937	0.5	3.8	0.4	57.2	30.3	3.0	4.8
27	3	1,200	1,166	-5.7	1,230	1,195	-7.9	1,100	0.6	3.5	3.1	64.0	21.1	1.7	6.0
28	1	430	430	-15.3	440	440	-17.3	364	—	0.8	1.6	65.7	28.6	0.8	2.5
30	2	990	970	-8.0	980	960	-7.1	892	—	2.0	5.6	56.9	27.0	1.7	6.8
All diameters	238	48,980	47,387	-5.0	45,580	43,819	2.7	45,000	6.1	8.1	6.6	43.0	25.7	6.6	3.9

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	SAP	1C	2A	2B	3C
1/2	—	—	—	—	—	0.3	—
5/8	—	0.6	0.3	0.1	—	—	—
3/4	6.0	1.0	1.4	1.2	2.0	2.2	1.8
4/4	75.4	81.0	53.4	82.2	75.0	77.0	80.9
5/4	0.4	6.0	5.2	0.2	1.4	3.5	3.5
6/4	16.3	9.6	27.4	15.8	10.6	0.7	3.5
7/4	—	—	—	—	0.1	—	—
8/4	1.9	1.8	12.3	0.5	10.9	16.3	10.3
Total tally (board feet)	2,726	3,622	2,988	19,364	11,546	2,982	1,772

Table 35.—YELLOW POPLAR: log grade 2: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	SAP	1C	2A	2B	3C
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
10	22	1,130	1,118	2.1	890	880	29.8	1,142	1.4	3.4	1.0	30.9	32.7	20.6	10.0
11	75	4,685	4,559	0.1	3,740	3,635	25.5	4,562	0.4	0.7	3.2	27.1	32.6	23.6	12.4
12	81	6,225	6,014	-1.3	5,290	5,088	16.7	5,936	0.7	2.9	2.8	29.2	36.7	20.3	7.4
13	72	6,720	6,497	-4.8	5,630	5,425	14.0	6,184	0.9	3.1	2.6	30.9	36.9	19.6	6.0
14	61	6,250	6,002	-2.3	5,440	5,200	12.7	5,861	0.9	2.7	3.8	31.8	36.5	16.2	8.1
15	65	8,380	8,193	-7.0	7,620	7,426	2.6	7,618	1.9	4.8	3.5	32.8	31.1	19.7	6.2
16	66	9,775	9,373	-4.3	8,820	8,401	6.7	8,967	1.6	6.1	2.6	34.1	30.8	20.9	3.9
17	35	6,225	6,055	-5.1	5,580	5,365	7.1	5,748	2.3	2.5	3.6	46.3	29.9	11.8	3.6
18	33	6,420	6,032	-3.2	5,960	5,523	5.7	5,837	2.7	6.0	3.3	38.9	31.7	11.0	6.4
19	27	6,045	5,850	-6.5	5,640	5,424	0.8	5,468	5.9	8.4	4.0	39.5	31.2	9.3	1.7
20	12	2,935	2,741	-7.0	2,840	2,584	-1.3	2,550	3.0	4.2	1.0	41.2	36.5	9.5	4.6
21	9	2,590	2,569	-1.9	2,450	2,430	3.7	2,520	2.3	4.6	3.1	51.7	27.5	9.1	1.7
22	4	1,000	995	-13.0	960	955	-9.3	866	2.2	2.2	0.8	35.2	39.1	14.3	6.2
23	1	335	335	-9.9	330	330	-8.5	302	—	—	—	50.0	43.0	7.0	—
24	4	1,250	1,206	-9.5	1,210	1,157	-5.7	1,091	1.4	5.0	—	48.4	34.5	7.0	3.7
25	1	340	340	-13.2	340	340	-13.2	295	—	—	—	39.0	57.3	3.7	—
27	2	1,010	983	-13.2	1,030	991	-13.9	853	14.0	24.5	2.6	44.4	8.2	0.9	5.4
All diameters	570	71,315	68,862	-4.4	63,770	61,154	7.6	65,800	2.1	4.5	3.0	35.8	32.8	16.1	5.7

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	SAP	1C	2A	2B	3C
1/2	—	—	—	—	0.1	—	—
5/8	—	0.9	—	0.2	—	—	0.1
3/4	3.6	1.3	1.6	2.1	1.9	3.4	3.3
4/4	90.2	93.2	79.8	87.4	87.4	79.2	79.8
5/4	0.7	0.5	—	0.3	0.8	1.7	2.2
6/4	5.5	3.0	11.7	8.7	4.6	0.8	5.3
7/4	—	—	—	—	0.3	0.4	—
8/4	—	1.1	6.9	1.3	4.9	14.5	9.3
Total tally (board feet)	1,370	2,976	1,968	23,574	21,559	10,586	3,767

Table 36.—YELLOW POPLAR: log grade 3: dry lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)						
		Int. 1/4-inch rule			Scribner Decimal C rule										
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	SAP	1C	2A	2B	3C
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*						
8	43	1,230	1,206	4.0	940	921	36.2	1,254	—	0.2	0.2	5.0	17.2	54.1	23.3
9	88	3,250	3,196	-2.2	2,720	2,667	17.2	3,125	—	0.3	0.2	7.1	20.6	49.7	22.1
10	114	5,610	5,474	-3.6	4,610	4,497	17.3	5,275	—	—	0.1	10.0	30.3	47.1	12.5
11	98	5,795	5,611	-0.6	4,670	4,528	23.2	5,578	0.1	0.3	0.4	11.5	30.9	41.9	14.9
12	89	6,665	6,450	-5.5	5,690	5,485	11.2	6,098	—	0.5	0.9	14.3	35.1	38.5	10.7
13	78	7,085	6,828	-3.7	5,990	5,750	14.3	6,573	—	0.1	1.0	18.6	37.9	34.9	7.5
14	60	6,290	5,963	-6.1	5,410	5,091	10.0	5,598	0.1	0.7	0.5	21.7	36.9	33.7	6.4
15	56	7,430	7,234	-7.2	6,670	6,445	4.1	6,712	0.1	0.7	1.3	24.0	41.9	26.3	5.7
16	41	5,645	5,506	-3.2	5,120	4,975	7.1	5,328	0.2	2.5	1.1	31.1	38.7	21.1	5.3
17	20	3,460	3,340	-5.3	3,120	2,989	5.8	3,162	1.1	1.8	0.7	40.1	35.9	15.0	5.4
18	15	3,240	3,123	-6.7	2,990	2,869	1.6	2,915	1.0	2.5	2.6	40.3	29.6	21.9	2.1
19	14	2,985	2,892	-1.8	2,790	2,701	5.2	2,841	0.4	2.5	1.8	35.6	35.6	20.6	3.5
20	9	2,450	2,444	-3.2	2,370	2,364	0.1	2,367	3.5	2.6	0.5	54.2	23.6	14.4	1.2
21	2	310	288	-6.3	300	277	-2.5	270	—	—	21.5	43.3	33.3	1.9	—
22	5	1,495	1,444	-7.2	1,410	1,341	-0.1	1,340	9.0	4.9	9.3	37.9	16.8	12.9	9.2
23	1	285	285	-4.9	280	280	-3.2	271	—	—	—	29.2	41.3	24.0	5.5
24	1	310	270	-16.3	300	244	-7.4	226	—	—	—	38.1	49.5	12.4	—
26	1	240	235	-11.9	250	245	-15.5	207	—	—	—	21.7	50.3	6.3	21.7
27	2	870	870	-14.1	890	890	-16.1	747	—	2.0	4.0	43.9	34.0	11.1	5.0
All diameters	737	64,645	62,659	-4.4	56,520	54,559	9.8	59,887	0.5	1.1	1.2	23.3	33.7	31.5	8.7

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	SAP	1C	2A	2B	3C
1/2	—	—	—	—	—	0.1	0.2
5/8	—	0.3	—	—	0.1	—	—
3/4	—	—	2.9	1.4	1.8	2.1	2.4
4/4	100.0	97.1	90.7	94.8	93.3	88.5	83.7
5/4	—	1.0	—	0.1	1.1	2.4	2.4
6/4	—	1.6	6.4	2.8	1.4	0.1	2.0
7/4	—	—	—	—	0.3	0.6	—
8/4	—	—	—	0.9	2.0	6.2	9.3
Total tally (board feet)	309	630	699	13,935	20,204	18,879	5,231

Table 37.—BEECH: log grade 1: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)								
		Int. 1/4-inch rule			Scribner Decimal C rule												
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE	TBR
		--Board feet--		*Percent*	*--Board feet----*		*Percent*	*Board feet*	*----------Percent----------*								
13	11	900	890	-7.0	770	762	8.7	828	7.2	13.5	38.4	9.5	—	9.5	21.9	—	—
14	5	550	539	-9.3	480	470	4.0	489	33.2	6.5	32.3	12.5	—	8.8	6.7	—	—
15	7	785	711	-6.3	750	679	-1.9	666	14.7	15.6	39.9	10.7	—	3.5	15.6	—	—
16	16	2,305	2,207	-0.7	2,090	2,001	9.5	2,191	25.1	8.9	33.9	12.8	0.5	3.9	14.9	—	—
17	9	1,445	1,364	3.5	1,320	1,247	13.2	1,412	8.4	2.5	47.1	18.4	—	8.1	15.5	—	—
18	12	2,070	1,977	-2.4	1,950	1,862	3.6	1,929	31.3	5.5	31.5	10.8	—	7.5	12.3	—	1.1
19	11	2,300	2,194	0.5	2,160	2,060	7.0	2,204	25.9	3.7	36.9	13.7	—	4.4	15.4	—	—
20	17	3,780	3,488	2.2	3,730	3,441	3.5	3,563	28.4	5.5	36.4	12.6	—	4.2	11.0	—	1.9
21	13	3,110	2,955	5.8	3,030	2,879	8.5	3,125	33.1	6.3	31.4	10.3	—	3.0	15.3	0.2	0.4
22	6	1,650	1,640	-3.3	1,580	1,570	1.0	1,586	28.2	2.5	38.1	14.8	—	6.5	9.9	—	—
23	6	1,760	1,642	-4.9	1,730	1,614	-3.2	1,562	27.8	1.5	42.9	8.9	—	4.0	14.9	—	—
24	2	680	661	5.4	650	632	10.3	697	25.0	1.7	36.0	12.8	—	7.3	15.6	1.6	—
All diameters	115	21,335	20,268	-0.1	20,240	19,217	5.4	20,252	26.0	5.6	36.4	12.3	0.1	5.1	13.9	0.1	0.5

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE	TBR
5/8	23.2	7.6	27.2	11.1	—	—	0.6	—	—
3/4	0.1	—	0.1	0.2	—	—	—	—	—
4/4	20.2	23.1	25.2	32.6	—	28.4	41.3	—	100.0
5/4	20.4	26.3	20.7	21.9	—	8.9	5.7	—	—
6/4	16.0	31.1	12.9	6.6	100.0	7.6	1.8	—	—
7/4	—	—	1.0	13.0	—	22.5	36.9	100.0	—
8/4	18.4	11.9	11.8	14.6	—	32.6	12.6	—	—
12/4	1.7	—	1.1	—	—	—	1.1	—	—
Total tally (board feet)	5,266	1,135	7,373	2,495	12	1,046	2,808	16	101

Table 38.—BEECH: log grade 2: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)								
		Int. 1/4-inch rule			Scribner Decimal C rule												
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE	TBR
		- - Board feet - -		*Percent*	*- - - Board feet - - -*		*Percent*	*Board feet*	*- - - - - - - - - - - - - - - - - - Percent - - - - - - - - - - - - - - - - - -*								
10	6	255	255	-5.9	180	180	33.3	240	3.3	—	32.5	36.2	—	11.7	16.3	—	—
11	18	1,080	1,017	-0.3	860	810	25.2	1,014	2.9	6.1	22.1	18.3	3.3	6.8	40.5	—	—
12	49	3,590	3,384	-5.0	3,030	2,856	12.6	3,215	1.9	3.6	27.5	21.1	0.7	12.9	32.3	—	—
13	48	3,910	3,750	-9.8	3,310	3,173	6.6	3,381	5.1	5.8	29.5	23.8	1.3	6.2	27.7	—	0.6
14	65	6,325	5,928	-2.3	5,560	5,212	11.1	5,790	5.4	6.1	31.6	24.1	0.6	9.3	22.9	—	—
15	50	5,855	5,575	-2.9	5,400	5,142	5.3	5,413	6.8	6.1	34.1	22.4	0.3	8.8	20.7	—	0.8
16	41	5,110	4,659	-2.8	4,670	4,259	6.3	4,527	7.6	4.4	37.5	23.3	0.2	5.7	20.8	—	0.5
17	34	5,010	4,845	-4.0	4,600	4,447	4.6	4,652	6.6	3.8	40.4	21.1	0.9	4.3	22.9	—	—
18	22	3,485	3,319	-0.2	3,310	3,151	5.2	3,314	8.4	4.0	34.9	21.9	0.2	8.4	22.2	—	—
19	25	4,865	4,711	-1.0	4,590	4,445	4.9	4,664	8.7	4.2	44.6	20.2	—	5.4	16.9	—	—
20	9	1,785	1,650	2.1	1,780	1,645	2.4	1,685	8.1	3.5	41.3	25.5	—	4.5	15.1	—	2.0
21	10	2,615	2,607	-4.3	2,510	2,502	-0.3	2,495	9.5	3.9	42.1	13.7	—	10.5	16.7	—	3.6
22	5	1,395	1,364	5.4	1,330	1,300	10.5	1,437	4.8	7.2	45.3	21.6	—	3.7	12.5	—	4.9
24	3	990	848	-5.1	950	815	-1.2	805	5.6	3.6	51.0	18.9	—	11.7	9.2	—	—
25	3	1,260	1,207	18.1	1,260	1,207	18.1	1,425	8.0	1.4	56.6	17.5	—	1.8	14.7	—	—
All diameters	388	47,530	45,119	-2.4	43,340	41,144	7.1	44,057	6.6	4.7	36.9	21.7	0.5	7.3	21.7	—	0.6

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE	TBR
5/8	8.8	3.1	11.0	5.1	—	0.2	0.1	—	—
3/4	—	—	0.1	0.1	—	0.1	0.2	—	—
4/4	28.7	21.5	31.0	36.0	3.7	45.1	49.6	—	100.0
5/4	11.4	6.2	15.8	15.8	—	6.8	3.3	—	—
6/4	45.0	56.8	33.4	27.0	96.3	16.7	11.5	—	—
7/4	—	—	0.3	4.5	—	13.1	25.1	—	—
8/4	6.1	12.4	8.4	11.2	—	18.0	10.2	—	—
12/4	—	—	—	0.3	—	—	—	—	—
Total tally (board feet)	2,895	2,076	16,255	9,554	214	3,242	9,543	—	278

Table 39.—BEECH: log grade 3: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale: Int. 1/4-inch rule Gross	Int. 1/4-inch rule Net	Int. 1/4-inch rule Overrun	Scribner Decimal C rule Gross	Scribner Decimal C rule Net	Scribner Decimal C rule Overrun	Total lumber tally	NHLA lumber grade yields (actual): FAS	SEL	1C	2C	SW	3A	3B	SSE	TBR
		-- Board feet --		Percent	-- Board feet --		Percent	Board feet	Percent								
8	6	145	140	1.4	120	115	23.5	142	—	—	7.7	2.8	4.2	—	85.3	—	—
9	13	530	510	-2.0	420	405	23.5	500	—	—	12.0	17.0	4.8	10.4	55.8	—	—
10	29	1,280	1,223	-5.9	1,050	1,005	14.5	1,151	—	0.5	11.4	23.8	3.4	6.5	54.4	—	—
11	25	1,285	1,197	-7.9	1,020	950	16.1	1,103	—	0.5	11.9	28.5	4.5	10.0	44.6	—	—
12	28	1,730	1,632	-4.9	1,500	1,416	9.6	1,552	—	0.5	15.7	26.7	4.6	10.2	42.3	—	—
13	24	1,855	1,705	-7.3	1,600	1,470	7.6	1,581	0.7	1.5	13.0	31.2	9.6	10.9	33.1	—	—
14	18	1,625	1,529	-14.1	1,430	1,346	-2.4	1,314	1.5	2.5	8.7	32.0	2.9	11.4	41.0	—	—
15	15	1,415	1,312	-3.8	1,340	1,243	1.5	1,262	1.7	—	20.0	37.2	1.4	9.0	30.7	—	—
16	8	870	837	—	800	770	8.7	837	—	—	28.3	19.8	—	8.0	43.9	—	—
17	2	330	330	13.9	300	300	25.3	376	—	—	31.9	39.1	—	18.4	10.6	—	—
18	4	650	539	-17.6	610	504	-11.9	444	—	2.5	29.1	37.1	—	13.7	17.6	—	—
19	6	940	905	-13.6	900	866	-9.7	782	—	—	16.1	32.2	—	10.4	41.3	—	—
20	3	560	540	-13.1	550	530	-11.5	469	—	—	24.9	35.4	—	13.9	25.8	—	—
21	2	435	321	13.1	420	310	17.1	363	3.3	—	46.1	22.0	—	7.7	20.9	—	—
22	2	525	525	-3.4	500	500	1.4	507	6.5	—	56.6	21.3	—	2.4	8.5	4.7	—
24	2	565	510	-2.0	550	496	0.8	500	2.2	2.4	51.8	29.8	—	4.8	9.0	—	—
All diameters	187	14,740	13,755	-6.3	13,110	12,226	5.4	12,883	0.8	0.8	20.1	28.8	3.1	9.6	36.6	0.2	—

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE	TBR
5/8	—	—	0.4	0.4	—	—	—	—	—
4/4	37.6	13.7	40.3	40.8	8.1	50.6	62.9	—	—
5/4	11.9	—	4.9	5.8	—	5.5	0.8	—	—
6/4	50.5	76.0	50.8	47.2	91.9	31.9	22.1	—	—
7/4	—	—	0.7	0.9	—	0.9	8.8	—	—
8/4	—	10.3	2.9	4.3	—	11.1	5.4	—	—
12/4	—	—	—	0.6	—	—	—	100.0	—
Total tally									

Table 40.—COTTONWOOD: log grade 1: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
13	9	810	738	27.1	660	601	56.1	938	11.9	5.5	35.9	44.4	2.3	—
14	11	1,235	1,158	21.1	1,060	995	40.9	1,402	22.3	10.3	31.2	28.7	4.4	3.1
15	17	2,105	2,090	8.5	1,960	1,946	16.5	2,267	27.6	5.9	26.0	34.3	3.6	2.6
16	27	3,875	3,704	12.7	3,530	3,375	23.7	4,174	26.0	4.4	33.3	31.3	3.6	1.4
17	22	3,610	3,523	13.5	3,300	3,222	24.1	3,997	29.0	9.5	30.5	25.3	2.1	3.6
18	14	2,500	2,418	13.2	2,350	2,273	20.4	2,736	37.8	8.2	29.8	19.8	1.6	2.8
19	12	2,490	2,406	14.3	2,340	2,261	21.7	2,751	36.2	6.4	29.3	21.3	2.0	4.8
20	11	2,710	2,690	11.7	2,650	2,630	14.3	3,006	44.6	4.9	27.2	21.7	1.1	0.5
21	5	1,350	1,340	4.2	1,300	1,290	8.2	1,396	39.4	1.5	25.6	24.6	5.6	3.3
22	5	1,575	1,554	19.0	1,490	1,470	25.8	1,849	59.6	6.7	19.0	12.6	2.1	—
23	2	780	780	6.0	760	760	8.8	827	55.0	6.8	26.2	12.0	—	—
24	4	1,470	1,470	4.6	1,400	1,400	9.8	1,537	38.5	3.7	39.3	17.3	0.7	0.5
25	4	1,540	1,540	14.5	1,540	1,540	14.5	1,764	44.4	7.9	30.9	11.5	2.0	3.3
26	1	435	435	16.8	440	440	15.5	508	21.3	1.4	62.8	10.0	4.5	—
27	3	1,410	1,410	4.1	1,440	1,440	1.9	1,468	38.3	3.3	37.6	18.3	1.5	1.0
28	3	1,600	1,479	15.7	1,600	1,480	15.6	1,711	48.8	2.4	30.4	13.5	2.6	2.3
29	2	1,090	1,063	8.6	1,060	1,034	11.6	1,154	42.8	3.2	26.1	20.4	4.4	3.1
31	2	1,440	1,440	11.1	1,420	1,420	12.7	1,600	75.0	6.9	7.3	10.1	0.7	—
32	2	1,340	1,340	-6.3	1,290	1,290	-2.7	1,255	37.7	2.8	45.6	8.0	—	5.9
33	2	1,425	1,425	29.3	1,370	1,370	34.5	1,842	59.7	0.8	28.9	5.3	2.4	2.9
All diameters	158	34,790	34,003	12.3	32,960	32,237	18.4	38,183	39.1	5.6	29.9	20.9	2.3	2.2

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
4/4	96.8	90.0	96.5	84.2	85.3	84.8
6/4	2.9	10.0	3.3	2.4	4.9	3.3
7/4	—	—	0.2	12.8	—	9.6
8/4	0.3	—	—	0.6	9.8	2.3
Total tally (board feet)	14,922	2,134	11,401	7,980	886	859

Table 41.—COTTONWOOD: log grade 2: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
10	3	155	155	1.9	120	120	31.7	158	—	—	57.0	34.8	—	8.2
11	24	1,540	1,385	19.9	1,180	1,060	56.6	1,660	2.1	3.1	33.6	45.5	4.9	10.8
12	58	4,610	4,357	11.7	3,890	3,676	32.4	4,867	3.3	2.8	37.5	45.6	4.4	6.4
13	66	6,170	5,853	11.7	5,130	4,868	34.3	6,538	3.6	2.6	40.1	46.6	2.6	4.5
14	56	6,300	5,982	9.1	5,430	5,157	26.5	6,525	7.1	5.1	38.8	40.5	2.2	6.3
15	44	5,590	5,289	10.7	5,150	4,872	20.2	5,855	10.2	6.2	39.2	37.2	2.0	5.2
16	36	5,385	5,183	8.3	4,880	4,697	19.5	5,613	6.2	4.4	41.9	42.9	1.8	2.8
17	19	3,140	3,015	4.6	2,860	2,747	14.8	3,154	6.7	2.9	46.4	35.5	1.3	7.2
18	15	2,760	2,728	5.4	2,600	2,570	11.9	2,875	15.7	4.1	42.4	31.2	5.1	1.5
19	8	1,695	1,627	10.5	1,590	1,526	17.8	1,798	28.8	4.4	32.2	26.6	3.3	4.7
20	2	540	540	15.7	520	520	20.2	625	19.2	1.9	48.8	25.3	2.6	2.2
21	1	195	195	-2.1	190	190	0.5	191	10.5	4.7	53.9	30.9	—	—
22	3	825	814	5.3	790	780	9.9	857	23.3	4.4	43.8	21.8	3.0	3.7
All diameters	335	38,905	37,123	9.7	34,330	32,783	24.2	40,716	8.2	4.1	40.0	39.8	2.8	5.1

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
4/4	75.5	68.8	81.2	78.2	69.5	74.2
5/4	—	—	—	0.1	—	0.2
6/4	24.5	31.2	18.7	12.7	19.2	17.2
7/4	—	—	0.1	8.8	7.8	6.9
8/4	—	—	—	0.2	3.5	1.5
Total tally (board feet)	3,353	1,652	16,304	16,218	1,118	2,071

Table 42.—COTTONWOOD: log grade 3: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
9	5	205	205	20.5	160	160	54.4	247	—	—	17.0	45.7	7.7	29.6
10	19	1,020	932	0.8	820	746	25.9	939	—	—	26.4	59.4	0.7	13.5
11	5	375	358	12.8	320	305	32.5	404	—	1.7	13.4	70.3	4.2	10.4
12	8	665	562	19.4	560	474	41.6	671	—	—	22.1	63.3	10.6	4.0
13	8	710	701	14.6	590	582	38.0	803	—	0.6	20.4	74.3	1.5	3.2
14	10	1,045	1,000	17.4	920	880	33.4	1,174	2.6	2.5	34.3	58.4	—	2.2
15	4	535	527	-6.3	480	473	4.4	494	3.6	—	27.3	55.1	13.0	1.0
16	2	260	260	21.9	240	240	32.1	317	—	—	29.7	64.6	5.7	—
18	3	510	499	12.2	480	470	19.1	560	2.0	1.3	44.5	50.8	1.4	—
All diameters	64	5,325	5,044	11.2	4,570	4,330	29.5	5,609	1.1	0.9	27.4	61.0	3.8	5.8

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
4/4	59.7	87.5	95.0	84.1	76.1	77.9
5/4	—	—	0.3	0.5	—	—
6/4	40.3	12.5	4.7	9.0	15.2	12.6
7/4	—	—	—	6.0	—	9.5
8/4	—	—	—	0.4	8.7	—
Total tally (board feet)	60	48	1,537	3,422	216	326

Table 43.—ELM: log grade 1: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Overrun	Gross	Net	Overrun		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
13	22	2,230	2,096	6.5	1,890	1,778	25.5	2,232	12.5	6.9	36.7	23.1	7.6	13.2
14	32	3,810	3,502	4.9	3,230	2,971	23.7	3,675	27.0	11.5	28.8	12.8	2.9	17.0
15	25	3,550	3,222	4.8	3,180	2,889	16.9	3,378	26.3	11.4	30.4	15.1	2.5	14.3
16	43	6,790	6,196	5.4	6,110	5,575	17.1	6,530	21.2	10.6	28.8	17.8	6.3	15.3
17	41	7,280	6,482	6.1	6,550	5,835	17.9	6,877	29.1	10.3	27.9	15.3	1.6	15.8
18	29	5,950	5,380	9.4	5,500	4,975	18.3	5,887	31.0	8.8	24.1	14.9	2.7	18.5
19	25	5,555	4,956	5.9	5,190	4,630	13.4	5,249	30.0	5.3	30.4	14.9	1.2	18.2
20	22	5,345	4,558	5.9	5,220	4,450	8.4	4,825	25.7	12.8	29.3	16.6	1.6	14.0
21	12	3,505	3,177	4.9	3,330	3,020	10.4	3,334	37.6	6.9	25.6	19.8	—	10.1
22	15	4,845	4,178	7.6	4,550	3,925	14.5	4,495	34.9	6.5	26.1	17.0	—	15.5
23	5	1,535	1,438	7.2	1,500	1,405	9.8	1,542	49.7	5.1	22.4	6.7	—	16.1
24	3	935	779	-1.5	900	750	2.3	767	25.9	14.1	35.1	11.6	—	13.3
25	8	3,380	2,901	-10.6	3,390	2,910	-10.9	2,594	28.4	14.3	22.5	17.3	—	17.5
26	1	370	370	-6.2	370	370	-6.2	347	49.8	11.5	18.2	15.3	—	5.2
27	4	1,810	1,663	6.1	1,850	1,700	3.8	1,764	49.1	8.9	24.8	8.8	—	8.4
28	1	585	504	-6.0	580	500	-5.2	474	36.7	—	39.1	12.2	—	12.0
All diameters	288	57,475	51,402	5.0	53,340	47,683	13.2	53,970	29.4	9.4	27.9	15.8	2.2	15.3

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
3/8	1.2	—	1.0	0.3	1.0	—
3/4	—	—	—	—	0.8	0.1
4/4	47.2	42.7	66.1	76.4	75.3	84.7
5/4	1.0	1.3	1.2	0.7	2.2	0.2
6/4	5.4	0.9	4.1	3.0	—	2.6
7/4	—	0.4	0.2	0.6	6.1	2.1
8/4	3.0	2.5	4.8	5.4	12.3	7.6
9/4	—	—	—	—	—	2.7
10/4	31.4	35.9	15.7	11.6	—	—
12/4	10.8	16.3	6.9	2.0	2.3	—
Total tally (board feet)	15,928	5,050	15,042	8,503	1,185	8,262

Table 44.—ELM: log grade 2: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
10	24	1,260	1,142	4.6	1,050	947	26.2	1,195	3.4	1.8	24.5	32.0	1.3	37.0
11	59	3,925	3,656	3.4	3,160	2,945	28.4	3,782	4.2	3.8	27.9	28.5	7.1	28.5
12	63	4,925	4,431	11.7	4,180	3,761	31.6	4,950	8.0	3.5	29.4	26.3	8.6	24.2
13	66	6,165	5,542	5.0	5,190	4,668	24.6	5,817	6.6	4.2	34.8	26.1	6.9	21.4
14	64	7,255	6,390	5.7	6,230	5,483	23.2	6,756	3.9	5.3	32.7	32.3	6.0	19.8
15	47	6,505	5,766	0.0	5,850	5,180	11.3	5,764	12.4	5.6	28.7	27.8	5.4	20.1
16	23	3,490	3,055	2.0	3,140	2,750	13.3	3,116	5.3	6.5	35.3	31.2	6.9	14.8
17	23	4,105	3,631	-0.9	3,670	3,246	10.9	3,600	10.0	3.2	33.1	29.6	4.9	19.2
18	15	2,610	2,371	6.0	2,460	2,234	12.5	2,513	13.5	9.3	41.4	21.1	3.5	11.2
19	8	1,730	1,395	-12.3	1,620	1,307	-6.4	1,223	10.1	2.2	49.3	23.2	5.1	10.1
20	5	1,170	1,017	-6.3	1,150	1,000	-4.7	953	13.0	4.5	39.6	25.6	7.5	9.8
21	4	905	671	-17.0	870	645	-13.6	557	3.2	—	40.7	25.9	—	30.2
22	1	355	290	7.9	330	270	15.9	313	10.9	17.3	29.9	29.1	—	12.8
23	1	335	335	-3.0	330	330	-1.5	325	9.5	—	29.2	37.0	22.8	1.5
All diameters	403	44,735	39,692	3.0	39,230	34,766	17.5	40,864	7.7	4.7	32.8	28.2	6.2	20.4

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
3/8	0.4	0.1	1.3	0.1	—	0.2
3/4	0.4	—	1.3	0.8	0.4	0.4
4/4	64.1	49.0	75.3	75.8	66.1	66.6
5/4	8.1	15.0	6.2	6.9	3.6	1.0
6/4	8.2	4.2	3.0	1.9	—	3.2
7/4	—	—	0.1	1.1	4.8	5.3
8/4	5.1	7.9	7.0	11.0	25.1	19.9
9/4	—	—	—	0.1	—	3.4
10/4	0.8	6.3	0.5	0.8	—	—
12/4	12.9	17.5	5.3	1.5	—	—
Total tally (board feet)	3,154	1,937	13,416	11,520	2,516	8,321

Table 45.—ELM: log grade 3: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale: Int. 1/4-inch rule Gross	Int. 1/4-inch rule Net	Int. 1/4-inch rule Overrun	Scribner Decimal C rule Gross	Scribner Decimal C rule Net	Scribner Decimal C rule Overrun	Total lumber tally	NHLA lumber grade yields (actual): FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
8	5	130	130	-0.8	90	90	43.3	129	—	—	8.5	31.8	3.1	56.6
9	28	1,125	999	5.0	930	829	26.5	1,049	—	0.5	14.2	27.7	8.0	49.6
10	42	2,155	1,919	7.1	1,740	1,547	32.8	2,055	1.9	1.1	16.8	33.1	10.8	36.3
11	10	660	550	-4.2	510	425	24.0	527	—	—	3.8	52.0	1.5	42.7
12	13	1,010	878	5.0	860	747	23.4	922	1.6	2.0	21.3	41.2	13.0	20.9
13	10	945	734	6.8	790	617	27.1	784	2.7	—	16.1	41.4	5.0	34.8
14	3	295	251	13.1	260	220	29.1	284	—	—	27.8	49.0	—	23.2
15	6	715	599	6.5	660	552	15.6	638	—	6.4	15.0	41.2	4.5	32.9
16	8	1,170	955	7.2	1,060	865	18.4	1,024	10.3	0.4	21.5	42.4	7.8	17.6
17	3	560	505	13.3	500	450	27.1	572	—	—	15.7	51.2	0.9	32.2
18	2	400	319	-9.4	370	295	-2.0	289	5.2	—	15.6	45.6	—	33.6
19	2	450	439	-6.4	420	410	0.2	411	—	—	23.8	38.2	4.9	33.1
All diameters	132	9,615	8,278	4.9	8,190	7,047	23.2	8,684	2.3	1.0	17.0	39.3	7.0	33.4

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
3/8	—	—	0.7	0.2	—	—
5/8	—	—	—	0.7	—	—
3/4	—	—	0.7	1.1	—	—
4/4	49.3	21.4	71.6	72.9	54.4	64.7
5/4	11.3	39.3	20.9	11.1	11.7	1.3
6/4	5.6	—	0.4	—	—	0.9
7/4	—	—	—	1.7	2.6	9.5
8/4	—	9.8	5.7	8.4	31.3	21.5
9/4	—	—	—	—	—	0.9
12/4	33.8	29.5	—	3.9	—	—
16/4	—	—	—	—	—	1.2
Total tally						

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
13	41	4,310	4,170	15.9	3,650	3,530	36.9	4,831	21.5	9.7	32.5	26.1	8.4	1.8
14	42	5,125	4,966	12.5	4,320	4,187	33.4	5,587	31.0	10.1	28.7	20.1	8.4	1.7
15	42	6,070	5,863	8.4	5,410	5,227	21.6	6,357	27.7	9.9	28.6	24.7	8.3	0.8
16	52	8,490	8,187	13.5	7,620	7,346	26.5	9,290	39.6	8.8	24.6	19.1	5.8	2.1
17	31	5,905	5,658	12.1	5,240	5,019	26.4	6,342	36.8	7.2	28.8	20.0	6.0	1.2
18	29	6,100	5,941	14.3	5,670	5,522	23.0	6,792	39.1	8.4	26.9	17.3	7.1	1.2
19	20	4,430	4,233	18.2	4,140	3,957	26.4	5,003	41.6	7.8	22.9	18.0	6.6	3.1
20	13	3,330	3,213	13.2	3,240	3,125	16.4	3,636	38.1	8.5	23.4	20.5	8.3	1.2
21	7	2,075	1,977	8.7	1,970	1,878	14.4	2,149	39.9	7.3	33.1	13.2	4.5	2.0
22	4	1,325	1,325	13.4	1,240	1,240	21.2	1,503	50.7	7.5	18.7	14.4	6.7	2.0
23	4	1,350	1,264	16.1	1,320	1,236	18.8	1,468	34.9	4.2	39.5	14.9	4.4	2.1
25	1	400	300	15.7	400	300	15.7	347	23.3	7.5	52.2	3.2	2.3	11.5
26	2	935	842	-2.3	940	847	-2.8	823	49.0	1.6	29.6	6.8	1.9	11.1
27	1	540	540	3.1	550	550	1.3	557	39.4	5.2	37.2	13.5	—	4.7
All diameters	289	50,385	48,479	12.8	45,710	43,964	24.4	54,685	35.7	8.4	27.7	19.5	6.8	1.9

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
5/8	0.2	0.9	1.6	0.6	0.3	0.7
4/4	44.2	40.7	56.4	56.0	33.6	59.0
5/4	54.9	57.7	38.3	31.8	10.3	12.2
6/4	—	—	0.1	—	—	—
7/4	—	—	—	0.3	1.4	12.3
8/4	0.3	0.7	1.2	10.8	54.4	15.8
10/4	0.4	—	2.4	0.5	—	—
Total tally (board feet)	19,490	4,607	15,149	10,676	3,723	1,040

Table 47.—SAP GUM: log grade 2: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
10	21	1,185	1,156	11.2	950	926	38.8	1,285	1.7	7.5	28.3	41.6	11.8	9.1
11	66	4,495	4,281	12.2	3,510	3,348	43.5	4,805	4.5	6.5	24.7	40.1	20.2	4.0
12	112	9,525	9,207	10.8	8,000	7,733	31.9	10,200	7.4	7.2	28.1	38.3	13.2	5.8
13	94	9,490	9,173	10.4	8,010	7,742	30.8	10,128	10.3	6.0	29.2	35.5	15.0	4.0
14	89	10,655	10,327	10.3	9,020	8,743	30.2	11,386	9.4	6.6	32.3	32.9	13.6	5.2
15	77	10,430	10,230	4.4	9,460	9,277	15.1	10,676	12.0	5.8	36.2	30.8	12.9	2.3
16	49	7,570	7,368	8.8	6,840	6,658	20.4	8,018	10.2	3.8	38.1	34.6	10.9	2.4
17	30	5,315	5,179	10.8	4,780	4,657	23.2	5,738	14.0	4.6	40.7	31.6	7.9	1.2
18	17	3,100	2,908	7.1	2,910	2,731	14.0	3,114	16.0	3.1	41.0	28.5	7.7	3.7
19	8	1,800	1,800	8.1	1,680	1,680	15.8	1,945	23.4	10.4	32.3	23.1	7.0	3.8
20	4	1,080	971	18.0	1,040	935	22.6	1,146	13.6	2.9	28.4	25.6	2.6	26.9
21	2	640	640	6.9	600	600	14.0	684	5.8	—	61.4	16.1	13.2	3.5
23	2	620	610	11.5	610	600	13.3	680	23.2	4.9	39.1	26.9	5.9	—
All diameters	571	65,905	63,850	9.3	57,410	55,630	25.5	69,805	10.4	5.8	33.3	33.7	12.6	4.2

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
5/8	0.8	0.8	2.3	0.9	0.5	0.7
4/4	61.3	46.3	61.2	61.5	38.5	35.9
5/4	34.7	48.6	32.5	26.7	11.9	9.0
6/4	0.4	—	—	0.1	0.3	0.4
7/4	0.4	0.3	0.2	1.4	1.4	19.8
8/4	1.7	4.0	2.8	9.1	47.4	34.2
10/4	0.7	—	1.0	0.3	—	—
Total tally (board feet)	7,305	4,065	23,225	23,502	8,777	2,931

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)					
		Int. 1/4-inch rule			Scribner Decimal C rule									
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	3A	3B
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*					
8	2	80	73	42.5	60	55	89.1	104	—	—	23.1	55.7	12.5	8.7
9	40	1,805	1,759	13.4	1,370	1,335	49.4	1,994	1.3	3.9	10.2	42.0	16.5	26.1
10	62	3,365	3,198	11.5	2,680	2,547	40.0	3,565	1.0	1.5	12.7	50.0	25.3	9.5
11	45	3,095	3,028	12.6	2,470	2,419	41.0	3,410	—	0.6	10.9	49.1	26.2	13.2
12	41	3,340	3,273	17.8	2,810	2,754	39.9	3,854	1.0	0.9	18.8	47.7	22.4	9.2
13	36	3,585	3,501	6.7	2,980	2,912	28.3	3,736	1.6	1.5	18.2	53.5	19.6	5.6
14	24	2,830	2,775	14.4	2,420	2,372	33.8	3,174	0.9	1.5	21.4	46.0	21.1	9.1
15	19	2,485	2,438	13.7	2,270	2,228	24.4	2,771	3.0	1.5	24.9	49.5	14.8	6.3
16	16	2,380	2,335	14.0	2,160	2,120	25.6	2,662	4.6	2.2	34.2	42.3	11.1	5.6
17	6	1,015	1,009	5.3	920	914	16.2	1,062	0.8	1.0	41.0	42.3	10.1	4.8
18	8	1,570	1,567	6.8	1,450	1,447	15.7	1,674	2.9	2.5	25.0	43.6	11.2	14.8
19	3	605	579	18.3	570	545	25.7	685	—	—	38.7	39.0	12.1	10.2
20	1	210	210	-8.1	210	210	-8.1	193	—	—	24.9	73.0	—	2.1
21	1	235	228	-3.9	230	223	-1.8	219	7.3	—	39.7	32.9	8.2	11.9
All diameters	304	26,600	25,973	12.1	22,600	22,081	31.8	29,103	1.6	1.5	20.6	47.5	18.9	9.9

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	3A	3B
5/8	0.8	2.5	4.8	1.9	1.4	3.0
4/4	49.7	43.4	64.1	63.8	47.5	45.0
5/4	45.4	49.6	27.1	22.1	10.6	5.4
6/4	—	—	—	0.3	0.4	1.7
7/4	—	—	—	1.0	1.4	17.5
8/4	4.1	4.5	4.0	10.9	38.7	27.4
Total tally (board feet)	467	442	5,991	13,805	5,502	2,892

Table 49.—RED OAK (lowland): log grade 1: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
		--Board feet--		*Percent*	*--Board feet--*		*Percent*	*Board feet*	*Percent*							
13	16	1,630	1,550	17.9	1,370	1,303	40.2	1,827	15.0	7.4	31.9	21.3	—	7.8	11.8	4.8
14	25	3,025	2,993	12.7	2,560	2,533	33.2	3,374	26.6	9.3	26.7	16.4	—	7.5	7.4	6.1
15	32	4,460	4,385	13.0	4,000	3,933	25.9	4,953	23.2	11.3	29.5	13.7	0.2	6.2	7.1	8.8
16	60	9,230	8,908	11.3	8,330	8,039	23.3	9,911	18.9	9.9	31.2	15.2	—	9.9	9.3	5.6
17	40	7,440	7,249	8.1	6,630	6,460	21.3	7,835	29.4	7.5	28.2	14.9	—	7.9	4.6	7.5
18	34	6,830	6,506	11.9	6,360	6,058	20.2	7,279	25.1	9.7	32.1	12.3	—	4.2	5.2	11.4
19	29	6,420	6,173	6.7	6,000	5,769	14.2	6,586	30.7	6.4	34.4	13.2	—	6.8	4.3	4.2
20	27	6,670	6,376	4.3	6,520	6,233	6.7	6,653	33.8	8.5	26.5	10.6	0.9	5.0	8.4	6.3
21	16	4,705	4,557	1.5	4,470	4,329	6.9	4,627	40.3	7.6	26.5	8.0	—	2.5	5.1	10.0
22	13	4,180	4,051	5.2	3,930	3,809	11.9	4,262	30.1	6.3	34.9	10.7	—	5.3	10.3	2.4
23	14	4,720	4,598	4.9	4,620	4,501	7.2	4,824	30.9	9.1	32.6	9.3	—	4.2	9.1	4.8
24	4	1,645	1,639	1.0	1,550	1,544	7.3	1,656	25.7	8.6	41.3	6.8	—	3.3	3.1	11.2
25	4	1,600	1,506	6.0	1,600	1,506	6.0	1,597	33.2	4.1	36.7	16.3	—	4.9	2.0	2.8
26	1	305	305	-19.3	310	310	-20.6	246	10.2	—	42.7	30.8	—	4.3	12.0	—
27	2	1,080	1,051	-2.7	1,100	1,070	-4.4	1,023	34.1	16.2	24.0	6.8	—	4.4	3.8	10.7
All diameters	317	63,940	61,847	7.8	59,350	57,397	16.1	66,653	27.8	8.6	30.8	12.8	0.1	6.2	6.9	6.8

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
4/4	48.9	65.1	82.0	94.9	100.0	93.5	74.5	—
8/4	50.6	34.9	17.9	5.1	—	6.5	25.5	23.8
12/4	0.5	—	0.1	—	—	—	—	76.2
Total tally (board feet)	18,553	5,706	20,519	8,553	68	4,130	4,593	4,531

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
		--Board feet--		*Percent*	*--Board feet--*		*Percent*	*Board feet*	*Percent*							
10	2	120	112	18.8	100	93	43.0	133	—	7.9	33.1	15.7	—	27.6	15.7	—
11	35	2,585	2,462	11.9	2,080	1,981	39.1	2,755	6.2	4.5	27.8	23.4	—	12.4	14.8	10.9
12	55	4,960	4,773	8.1	4,160	4,003	28.9	5,158	5.3	3.7	30.2	22.2	—	12.9	18.1	7.6
13	68	7,045	6,882	7.2	5,960	5,822	26.7	7,376	5.0	4.2	26.8	24.3	—	14.8	17.2	7.7
14	57	6,745	6,637	3.8	5,730	5,638	22.2	6,889	7.1	5.0	28.4	23.4	0.5	14.5	18.3	2.8
15	72	10,240	9,824	2.4	9,140	8,769	14.7	10,059	5.7	4.1	29.1	23.4	—	14.9	14.9	7.9
16	40	6,125	5,945	5.6	5,540	5,377	16.8	6,278	4.8	6.0	39.4	20.8	0.4	10.8	12.0	5.8
17	33	5,920	5,861	0.4	5,300	5,247	12.1	5,882	8.3	6.0	33.6	17.7	0.2	9.4	17.7	7.1
18	30	5,910	5,722	7.0	5,530	5,354	14.3	6,122	8.0	3.8	40.9	16.5	—	9.0	12.3	9.5
19	22	4,775	4,617	1.4	4,470	4,322	8.3	4,680	10.1	4.8	34.6	22.6	—	13.0	12.1	2.8
20	5	1,250	1,071	7.7	1,220	1,045	10.3	1,153	12.2	2.7	27.8	19.0	—	14.0	21.0	3.3
21	4	1,155	1,134	3.7	1,100	1,080	8.9	1,176	3.8	8.2	35.1	20.0	2.5	14.5	8.8	7.1
22	4	1,175	1,175	1.1	1,120	1,120	6.1	1,188	11.8	4.0	35.5	18.4	—	10.3	7.8	12.2
23	1	335	335	-16.4	330	330	-15.2	280	3.4	4.1	38.6	30.0	—	4.1	4.1	15.7
24	6	2,385	2,081	-0.6	2,250	1,963	5.4	2,069	8.9	3.2	50.2	16.1	—	8.4	6.2	7.0
All diameters	434	60,725	58,631	4.4	54,030	52,144	17.4	61,198	6.8	4.6	32.9	21.3	0.2	12.5	14.8	6.9

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
4 4	69.9	67.3	90.8	95.7	100.0	93.5	71.4	—
6 4	—	—	0.1	—	—	—	—	—
8 4	30.1	32.7	9.1	4.3	—	6.5	27.9	39.1
12 4	—	—	—	—	—	—	0.7	60.9
Total tally (board feet)	1,118	2,829	20,113	13,066	106	7,653	9,086	4,197

Table 51.—RED OAK (lowland): log grade 3: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
		--Board feet--		*Percent*	*--Board feet--*		*Percent*	*Board feet*	*Percent*							
8	7	275	275	4.7	200	200	44.0	288	—	—	19.7	8.4	—	11.7	36.9	23.3
9	10	490	476	8.4	380	369	39.8	516	1.6	1.6	14.1	20.4	—	8.3	32.0	22.0
10	20	1,180	1,173	4.9	980	974	26.3	1,230	1.2	1.2	21.4	20.7	—	16.0	25.9	13.6
11	15	1,070	1,032	16.2	850	820	46.2	1,199	—	1.5	12.6	32.9	—	24.5	25.9	2.6
12	15	1,315	1,242	8.3	1,100	1,039	29.5	1,345	—	0.4	19.3	32.1	—	20.4	21.5	6.3
13	28	2,725	2,525	-1.7	2,280	2,113	17.4	2,481	0.7	0.6	9.8	22.0	—	24.2	35.6	7.1
14	24	2,685	2,631	-1.3	2,320	2,273	14.3	2,598	1.2	0.7	13.5	23.7	0.2	21.3	33.4	6.0
15	15	1,915	1,890	-8.7	1,760	1,737	-0.6	1,726	0.4	0.7	24.7	30.3	—	19.2	19.4	5.3
16	5	725	689	8.4	660	627	19.1	747	—	—	23.5	24.3	—	23.6	28.6	—
17	12	1,975	1,931	4.1	1,800	1,760	14.2	2,010	0.8	2.9	32.4	31.7	—	9.9	16.7	5.6
18	6	1,230	1,219	1.0	1,140	1,130	8.9	1,231	3.1	4.9	22.2	21.8	—	19.3	23.0	5.7
19	3	605	594	-6.2	570	560	-0.5	557	—	0.8	46.0	22.1	—	12.8	18.3	—
20	6	1,540	1,511	1.3	1,500	1,472	3.9	1,530	0.8	0.7	27.2	30.9	—	17.4	23.0	—
21	1	235	235	-7.7	230	230	-5.7	217	—	—	34.3	26.6	—	21.2	17.9	—
22	2	710	700	-14.3	660	651	-7.8	600	—	—	34.0	41.9	—	15.9	8.2	—
All diameters	169	18,675	18,123	0.8	16,430	15,955	14.5	18,275	0.8	1.2	21.2	26.8	0.0	18.7	25.4	5.9

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
4/4	80.3	76.7	95.8	96.1	100.0	96.4	77.1	—
5/4	—	—	0.4	0.3	—	—	—	—
8/4	19.7	23.3	3.8	3.6	—	3.6	22.9	58.2
9/4	—	—	—	—	—	—	—	1.5
12/4	—	—	—	—	—	—	—	40.3
Total tally (board feet)	144	226	3,874	4,889	5	3,418	4,648	1,071

Table 52.—WHITE OAK (lowland): log grade 1: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
13	12	1,215	1,207	10.9	1,020	1,013	32.1	1,338	7.0	7.7	32.8	17.6	0.7	13.1	12.8	8.3
14	12	1,370	1,343	13.9	1,180	1,157	32.2	1,530	15.6	7.9	31.2	20.4	—	7.6	13.1	4.2
15	18	2,495	2,435	8.4	2,250	2,196	20.2	2,640	25.8	9.4	27.6	19.8	0.8	9.4	5.4	1.8
16	23	3,595	3,446	10.2	3,240	3,106	22.3	3,799	21.0	7.1	29.1	15.0	1.3	9.6	10.9	6.0
17	30	5,290	5,126	7.2	4,760	4,612	19.1	5,494	26.2	8.6	29.4	14.1	1.6	7.6	7.6	4.9
18	25	5,000	4,822	6.3	4,670	4,504	13.8	5,125	27.7	7.5	32.7	15.6	0.6	7.1	5.5	3.3
19	14	2,975	2,923	13.8	2,790	2,741	21.3	3,325	24.7	7.3	35.3	13.1	1.6	4.8	2.9	10.3
20	15	3,510	3,470	9.2	3,430	3,391	11.8	3,790	29.8	4.0	40.1	10.4	—	3.2	8.7	3.8
21	12	3,340	3,269	4.3	3,200	3,132	8.8	3,409	28.0	6.3	37.6	13.7	—	4.3	8.0	2.1
22	7	2,145	2,096	4.9	2,030	1,984	10.8	2,198	28.7	3.0	39.1	12.4	2.3	2.7	2.9	8.9
23	5	1,635	1,620	1.2	1,600	1,585	3.4	1,639	44.6	3.9	36.6	9.2	—	3.5	2.2	—
24	5	1,785	1,687	-5.2	1,700	1,607	-0.5	1,599	39.7	8.3	38.8	4.8	—	2.8	2.8	2.8
25	2	740	740	5.7	740	740	5.7	782	29.4	4.3	54.1	4.2	—	0.9	3.3	3.8
26	2	675	675	8.1	680	680	7.4	730	52.1	5.5	23.7	11.5	—	—	7.2	—
27	1	400	400	19.0	410	410	16.1	476	36.9	2.0	37.3	15.9	—	—	7.9	—
28	2	1,015	1,009	3.7	1,020	1,014	3.2	1,046	58.7	8.0	11.5	9.9	—	0.7	11.2	—
29	1	465	445	12.6	460	440	13.9	501	76.3	3.4	10.7	3.1	—	1.5	—	5.0
30	1	495	495	5.7	490	490	6.7	523	9.0	—	41.2	36.4	3.6	3.4	6.4	—
31	1	720	694	-9.2	710	684	-7.9	630	—	—	70.0	25.0	—	2.7	2.3	—
All diameters	188	38,865	37,902	7.0	36,380	35,486	14.3	40,574	28.1	6.5	33.8	14.0	0.8	5.7	6.8	4.3

Percentage distribution of log grade 1 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
4/4	69.0	75.2	90.1	92.4	100.0	92.9	64.1	—
5/4	0.1	0.9	1.9	2.2	—	1.6	0.8	—
6/4	—	—	0.1	0.3	—	—	—	—
7/4	—	—	0.1	0.9	—	—	6.5	—
8/4	3.6	2.1	1.2	2.4	—	5.5	25.5	35.3
10/4	26.3	20.6	6.0	1.8	—	—	3.1	—
12/4	1.0	1.2	0.6	—	—	—	—	64.7
Total tally (board feet)	11,398	2,658	13,701	5,667	321	2,334	2,753	1,742

Table 53.—WHITE OAK (lowland): log grade 2: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
10	4	204	206	36.1	210	180	55.6	280	2.6	3.8	20.6	29.6	—	20.2	10.5	12.7
11	27	1,880	1,863	14.1	1,530	1,516	40.2	2,125	0.9	2.5	18.1	28.0	1.9	20.9	21.8	5.9
12	48	4,025	3,910	15.1	3,390	3,293	36.6	4,499	4.3	3.8	24.9	26.6	3.2	13.1	15.9	8.2
13	50	5,075	4,968	17.7	4,240	4,151	40.8	5,846	3.2	1.2	26.2	29.9	1.0	15.2	10.7	12.6
14	50	5,920	5,838	9.9	5,030	4,960	29.4	6,417	5.5	2.9	29.7	26.6	1.2	11.6	13.9	8.6
15	61	8,615	8,455	7.4	7,710	7,567	20.0	9,077	4.5	3.4	30.0	23.3	2.7	13.5	12.7	9.9
16	40	6,085	5,904	11.3	5,500	5,336	23.1	6,571	4.8	3.1	36.4	26.6	1.2	9.0	7.7	11.2
17	38	6,410	6,220	10.9	5,800	5,628	22.6	6,901	6.6	3.5	30.9	25.0	1.9	10.3	11.0	10.8
18	35	6,670	6,370	6.0	6,240	5,959	13.3	6,750	6.8	3.7	40.6	18.3	2.9	6.2	8.2	13.3
19	17	3,515	3,399	3.5	3,300	3,191	10.2	3,518	12.2	6.4	35.5	19.6	1.3	9.4	11.3	4.3
20	8	1,850	1,848	4.0	1,810	1,808	6.3	1,922	11.8	3.8	43.5	19.4	—	3.3	10.3	7.9
21	8	1,930	1,892	17.3	1,860	1,823	21.7	2,219	12.0	1.7	45.6	20.3	1.2	4.8	8.0	5.9
22	9	2,445	2,233	9.2	2,330	2,128	14.6	2,438	10.1	3.4	37.5	19.4	5.5	10.4	10.1	3.6
24	4	1,305	1,305	5.7	1,250	1,250	10.3	1,379	21.0	3.4	41.8	15.6	1.9	2.3	1.9	12.1
25	1	400	400	2.0	400	400	2.0	408	17.7	—	20.6	28.0	8.7	5.2	2.3	17.5
26	2	740	692	-5.5	740	692	-5.5	654	7.2	3.0	46.9	29.7	4.0	2.1	7.1	—
27	1	470	470	3.2	480	480	1.0	485	—	—	32.0	35.5	8.0	8.0	16.5	—
All diameters	403	57,575	55,973	9.9	51,820	50,362	22.1	61,489	6.5	3.2	32.7	24.1	2.1	10.6	11.2	9.6

Percentage distribution of log grade 2 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
4/4	91.4	90.2	93.7	86.5	84.6	86.2	60.3	—
5/4	1.9	0.5	3.3	8.5	7.5	8.4	5.1	—
6/4	—	—	0.1	—	—	—	—	—
7/4	—	—	0.2	1.6	—	1.2	8.3	—
8/4	0.6	2.8	0.6	2.1	–	4.2	25.1	19.6
10/4	6.1	6.5	2.1	0.4	2.2	—	—	0.4
12/4	—	—	—	0.9	5.7	—	1.2	80.0
Total tally (board feet)	3,990	1,977	20,117	14,835	1,299	6,529	6,884	5,858

Table 54.—WHITE OAK (lowland): log grade 3: green lumber grade yield, by scaling diameter

Scaling diameter (inches)	No. logs	Scale						Total lumber tally	NHLA lumber grade yields (actual)							
		Int. 1/4-inch rule			Scribner Decimal C rule											
		Gross	Net	Over-run	Gross	Net	Over-run		FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
		Board feet		*Percent*	*Board feet*		*Percent*	*Board feet*	*Percent*							
8	1	40	40	30.0	30	30	73.3	52	—	8.0	20.0	—	—	52.0	20.0	—
9	8	375	369	17.6	290	285	52.3	434	—	2.9	13.3	21.3	—	33.2	19.6	9.7
10	25	1,465	1,427	14.5	1,230	1,198	36.4	1,634	0.5	—	17.7	33.3	1.5	14.6	25.6	6.8
11	16	1,185	1,170	12.4	950	938	40.2	1,315	0.6	0.3	17.7	21.2	3.3	13.9	32.8	10.2
12	15	1,145	1,099	18.1	970	931	39.4	1,298	—	1.2	14.7	27.6	5.7	13.4	18.5	18.9
13	27	2,715	2,666	14.3	2,290	2,249	35.4	3,046	0.5	0.3	13.7	30.5	0.4	17.4	23.6	13.6
14	17	1,895	1,873	8.3	1,640	1,621	25.2	2,029	—	1.4	8.1	40.4	4.9	12.0	16.0	17.2
15	20	2,550	2,364	8.4	2,320	2,151	19.2	2,563	—	—	19.8	24.1	3.3	14.5	21.1	17.2
16	18	2,890	2,740	15.9	2,600	2,465	28.9	3,177	1.4	1.3	20.8	30.3	6.6	15.1	9.3	15.2
17	13	2,235	2,180	7.8	2,020	1,970	19.2	2,349	0.4	0.8	14.7	28.3	2.6	9.7	14.0	29.5
18	11	2,110	2,009	11.3	1,970	1,876	19.2	2,237	0.5	2.9	23.9	33.0	4.4	11.1	13.5	10.7
19	6	1,385	1,338	1.0	1,290	1,246	8.5	1,352	—	—	15.3	40.4	8.4	8.6	7.8	19.5
20	5	1,095	1,085	0.3	1,070	1,060	3.6	1,098	—	—	17.2	31.0	15.7	10.1	7.1	18.9
21	5	1,265	901	2.1	1,220	869	5.9	920	—	1.0	25.1	27.1	1.1	13.6	28.9	3.2
22	3	830	830	19.5	790	790	25.6	992	—	1.6	16.4	46.2	—	7.8	7.1	20.9
23	1	285	285	25.6	280	280	27.9	358	—	—	17.6	37.5	5.6	14.1	8.5	16.7
All diameters	191	23,465	22,376	11.1	20,960	19,959	24.5	24,854	0.4	0.9	17.1	31.1	4.1	13.5	17.1	15.8

Percentage distribution of log grade 3 yields, by thickness

Lumber thickness (inches)	FAS	SEL	1C	2C	SW	3A	3B	SSE and TBR
4/4	100.0	92.0	95.0	88.5	91.8	90.0	76.1	—
5/4	—	8.0	4.0	8.0	8.2	7.1	3.0	—
6/4	—	—	—	0.1	—	—	—	—
7/4	—	—	—	0.2	—	—	2.9	—
8/4	—	—	—	0.9	—	—	18.0	15.6
10/4	—	—	1.0	0.6	—	2.9	—	—
12/4	—	—	—	1.7	—	—	—	84.4
Total tally (board feet)	100	224	4,264	7,731	1,020	3,353	4,244	2,918

Hanks, Leland F., Glenn L. Gammon, Robert L. Brisbin, and Everette D. Rast.
1980. Hardwood log grades and lumber grade yields for factory lumber logs. Northeast. For. Exp. Stn., Broomall, Pa.
92 p. (USDA For. Serv. Res. Pap. NE-468)

The USDA Forest Service Standard Grades for Hardwood Factory Lumber Logs are described, and lumber grade yields for 16 species and 2 species groups are presented by log grade and log diameter. The grades enable foresters, log buyers, and log sellers to select and grade those logs suitable for conversion into standard factory grade lumber. By using the appropriate lumber grade yields, log buyers and sellers can appraise the logs in terms of expected lumber grade volume and value. This report supersedes an earlier report on hardwood log grading, Forest Service Research Paper FPL 63.

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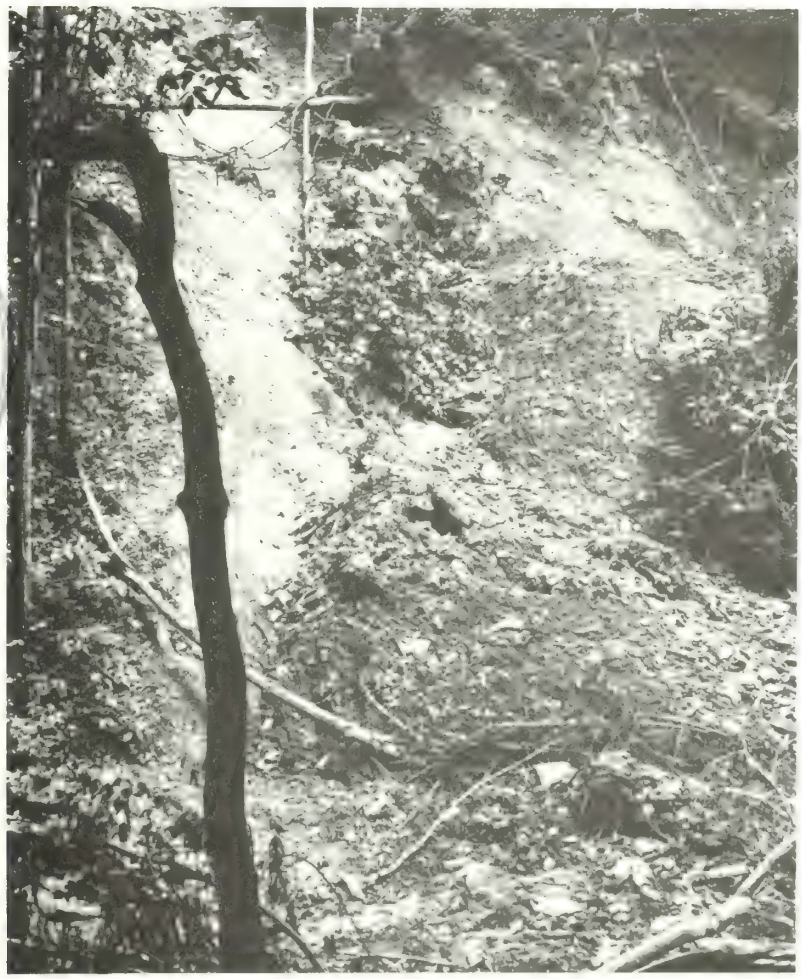

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Abstract

On May 24, 1978, heavy rain caused flash flooding on densely forested land near Parsons, in Tucker County, West Virginia. Poststorm evidences of soil and water behavior were examined in detail on soils related to the Dekalb and Leetonia series. Other flash floods struck seven forested sections of the state in August. Less detailed observation after these storms centered on the Weikert-Berks soil complex. Erosion in perennial channels was severe at all of the storm sites. Ephemeral channels had eroded severely in May but not in August, an effect attributed to higher soil moisture in May. Rain infiltrated completely into most of the forest floor during all of the storms; thus, overland flow occurred only when soils became saturated by infiltrated water draining downslope. Erosion of mineral soil was not apparent on the forest floor, regardless of steepness, even on grazed and cutover land. Neither did logging roads erode seriously. Rain was insufficient to cause widespread erosion by debris avalanching. Sediment production during these rare phenomenal storms was estimated to range from 3 to 10 tons per acre, a rate of loss comparable to the annual losses claimed for farmland. Water relations were similar on all of the soils observed, to the extent that each responded as predicted by the concept of variable source area for the origin of streamflow on forest soil.

INTRODUCTION

MOST HYDROLOGISTS hold to the conventional concept that streamflow is the result of runoff and aquifer discharge (Wadleigh 1966). The Water Resources Committee of the Soil Science Society of America defined runoff as:

> Runoff = (Precipitation)—(Surface Retention)—(Infiltration).
>
> During a major storm, surface retention becomes of very minor consequence so that amount of infiltration becomes the essential determinant of runoff during such a storm.

This is stormflow, or runoff, as usually defined by most engineers and agriculturists. According to this view, stormflow—rain that fails to infiltrate—reaches streams by flowing overland to them. But what if all the rain infiltrates? Does that ever happen? Forest hydrologists think that it does and, furthermore, that overland flow is a rarity in the humid climate forest. They believe that rate of infiltration (the maximum rate at which rain can enter the soil) almost always exceeds rainfall intensities on well-managed forest land throughout the eastern United States (Lull and Reinhart 1972). Miller (1977) concurs:

> Such large volumes of infiltration capacity suggest why many forested slopes in experimental basins, which have been closely observed for many years, have never been seen to produce surface runoff. Never have rates of rainfall exceeded the high rates of infiltration capacity into their upper soil layers.

The concept of variable source area (Hewlett and Troendle 1975) treats infiltration as seldom limiting on forest land. It postulates that headwater (first order) streams rise during intense storms because rain falls directly into their channels; indirectly, infiltrating rain begins to saturate certain of the soil strata and drains into seeps or into ordinarily dry hollows, and water flows within these ephemeral channels to a perennial stream. In effect, these indirect responses to unlimited infiltration cause an upslope expansion by the channel systems of first-order streams, transversely as well as longitudinally.

Infiltration over most of the forest floor continues for as long as the rain continues. Saturated strata (where infiltrated rain exceeds soil pore capacity) respond to increasing hydraulic gradients by flowing within the soil more or less in conformance to its slope. Direction, velocity, and volume of subsurface flows vary with depth of saturation and with

the conductivity, steepness, orientation, and depth of soil. Water exfiltrates from the soil when deepening strata of saturation rise to the surface. Exfiltrating water and uninfiltrated rain falling on saturated soil flow overland; these, too, are source areas but often are misinterpreted as runoff as defined by Wadleigh (1966). Source areas expand rapidly during intense rainfall and shrink slowly as rains diminish, draining lower slopes and shallow soils more rapidly and completely than upper slopes with deeper soil. The source area concept, simplified and diagramed in Figure 1, has obvious implications for the erosion of forest soil.

During 1978, I visited seven sites of flash flooding in northern and central West Virginia while the evidences of water behavior and soil erosion were fresh and fully visible on the forest floor. Observation in greatest detail was possible after the storm of May 24 in Tucker County; it skirted just north of the Parsons Timber and Watershed Laboratory. No other storm occurred so conveniently nearby; observation at other sites was limited to from a few hours to a few days. At each site, my purpose was to reconstruct water behavior on and within forest soils, an essential step in interpreting erosion losses from the storm sites.

THE SPRINGTIME STORM

On May 24, 1978, an intense rainstorm caused flash flooding and associated damages across Tucker County, West Virginia. The radar at Pittsburgh Airport, about 75 miles north-northwest, detected only light to moderate rain, with clouds to 18,000 feet, during the hours 9 a.m. to 3 p.m.[1] The

[1] Personal communication from Sterling Yeager, National Oceanic and Atmospheric Administration, Eklins, West Virginia.

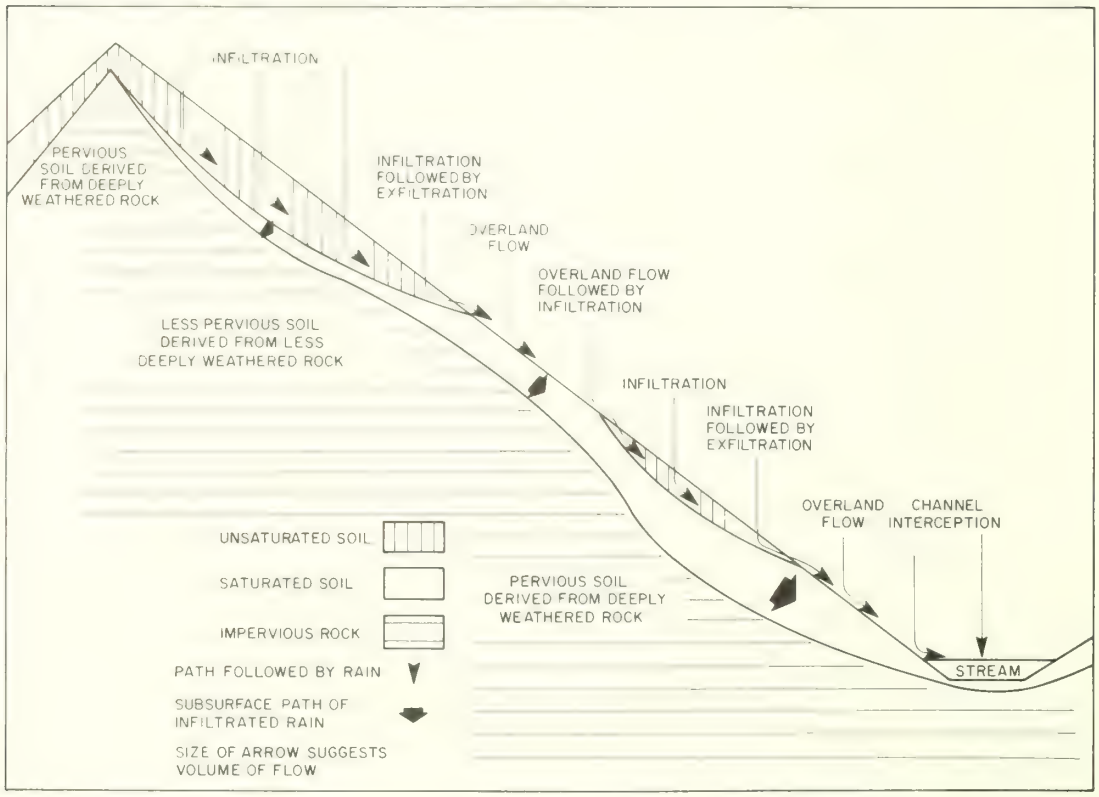

Figure 1.—Two-dimensional representation of rainfall disposition on a shallow forested soil.

igure 2.—Highway workers were pressed to eep Route 38 open to traffic as debris poured rom this unnamed draw near St. George. At his elevation (1,700 feet) tree foliage had lmost fully emerged.

HOTOGRAPH BY KENNETH SMITH, PARSONS ADVOCATE.

Figure 3.—Stormflow far exceeded the capacity of this ephemeral flow channel on Route 219. At this elevation (2,800 feet) tree foliage had only begun to emerge. Note small stones being washed along the road pavement.

report in the Parson Advocate of May 31 suggests that radar is not infallible:

> A cloudburst last Wednesday afternoon tore through a strip between Rt. 38 area, Sugarlands, US 219 near Mackeyville and Backbone Mountain, and in an area in Canaan Valley causing extensive damages . . .On Route 38 from the Barbour County line to St. George enormous amounts of rock and dirt were washed out of the hollows onto the roads and culverts were closed.

Fortunately, the proximity of this storm permitted a closer look at water behavior along its path. Water and debris had indeed poured in unprecedented volumes from normally dry hollows (Fig. 2). and ephermeral channels (Fig. 3), as well as from perennial headwater streams (Fig. 4). (Except where noted, photographs are by Forest Service personnel.)

My paramount concern was to establish the amount, timing, and extent of heaviest rainfall. A notice in the Parsons Advocate led to particularly useful information from the following respondents:

Figure 4.—Debris-laden stormflow in Jonathan Run at Route 72. The flooded stream is about 30 feet across and perhaps 4 feet deep. One can step across this stream during non-storm flow.

PHOTOGRAPH BY KENNETH SMITH, PARSONS ADVOCATE.

1. Mrs. Lana Oaster, Texas Mountain, elevation 2,750 feet. The rain began just as Mrs. Oaster delivered her daughter to the school bus at 7:15 a.m. The storm approached from west of their mountaintop home. The hardest rain fell between 9 a.m. and 11 a.m., and the storm ended at 1:30 p.m. On the previous evening, Mr. Oaster had left an empty 5-gallon bucket in the garden. It contained just under 6 inches of water after the storm. Water spurted upward when Mrs. Oaster walked on the waterlogged ground, where dense sod near the garden was raised several inches by water trapped between it and the underlying soil.
2. Mr. Miles Kochenderfer, Holly Meadows, elevation 1,740 feet. The rain began in midmorning and was heaviest during midday. At about 1 p.m., Mr. Kochenderfer recalled that grass on his lawn was covered by standing water. The grass was neatly mowed, perhaps 2 inches high, on a lawn sloping about 5 percent away from the house. Apparently, rain fell at the height of the storm faster than it could infiltrate into or flow across the grass-covered surface. A glass gage contained 4.20 inches of rain.
3. Mr. Ben Thompson, Canaan Valley, elevation 3,300 feet. Mr. Thompson is a longtime weather observer for NOAA. His official gage recorded 3.10 inches of rain. His notes record light rain from 6 a.m. to 11:30 a.m., heaviest rain from noon until 3 p.m. Several inches of water were pumped from Mr. Thompson's basement, never flooded before this storm.

From measurements and eyewitness accounts, it seems that rain fell at intensities close to 1-1/2 inches per hour for 3 hours near the western edge of Tucker County, for 2 hours near its eastern edge. Furthermore, rain at these intensities fell on fully wetted soil. Winter snow had melted early in April, more than 4 inches of rain had fallen earlier in May, and tree foliage had emerged too recently to draw down soil moisture by transpiration.

Distribution of high-intensity rain was determined by recording its poststorm evidences on a highway map of Tucker County. Every road in the storm vicinity was traveled in search of evidences such as deeply scoured streambeds and road ditches, slipouts along roads and streams, and debris deposits below hollows. A storm track about 30 miles long, about 3 miles wide at its western end, and less than 2 miles wide at its eastern end was thus defined (Fig. 5).

Reported amounts of rainfall, with roads and locations referred to in this report, were plotted on the storm track. Only one catch of heavy rainfall was reported outside the storm track; rain in a small glass gage, mounted on the flat side of a board, probably had been augmented by in-splash from the board. There were neither reports nor evidence of flash flooding at this location and an official standard gage less than 1 mile away had caught only 1.15 inches of rain.

SOIL-WATER RELATIONS AND EROSION ON THE DEKALB-CALVIN SOIL ASSOCIATION

The largest roadside debris deposits lay beneath outlets of hollows on Dekalb soil (Losche and Beverage 1967), near St. George on Routes 38 and 72. Here, the mountains are low but steep, ranging in elevation from 2,500 to 3,200 feet, in slope from 40 to 70 percent. The forest, predominantly oak and maple, had not been cut in many years.

After the storm, I walked into the forest above some of the larger debris deposits which were composed mostly of sandstone fragments, but contained much soil and organic detritus. Upslope, the bedrock was interbedded shale and fine-grained sandstone, with the shallowest soil usually overlying the shale. Sandstone fragments on the forest floor were flat, seldom thicker than 2 inches or wider than 12 inches. There was little or no surface rock were soils where underlain by shale.

My first concern was to search for evidences of overland flow. Hardwood litter blanketed most of the forest floor, usually 1 to 3 inches deep. Rearranged litter was interpreted as evidence of overland flow. Litter closest to channels often had washed away.

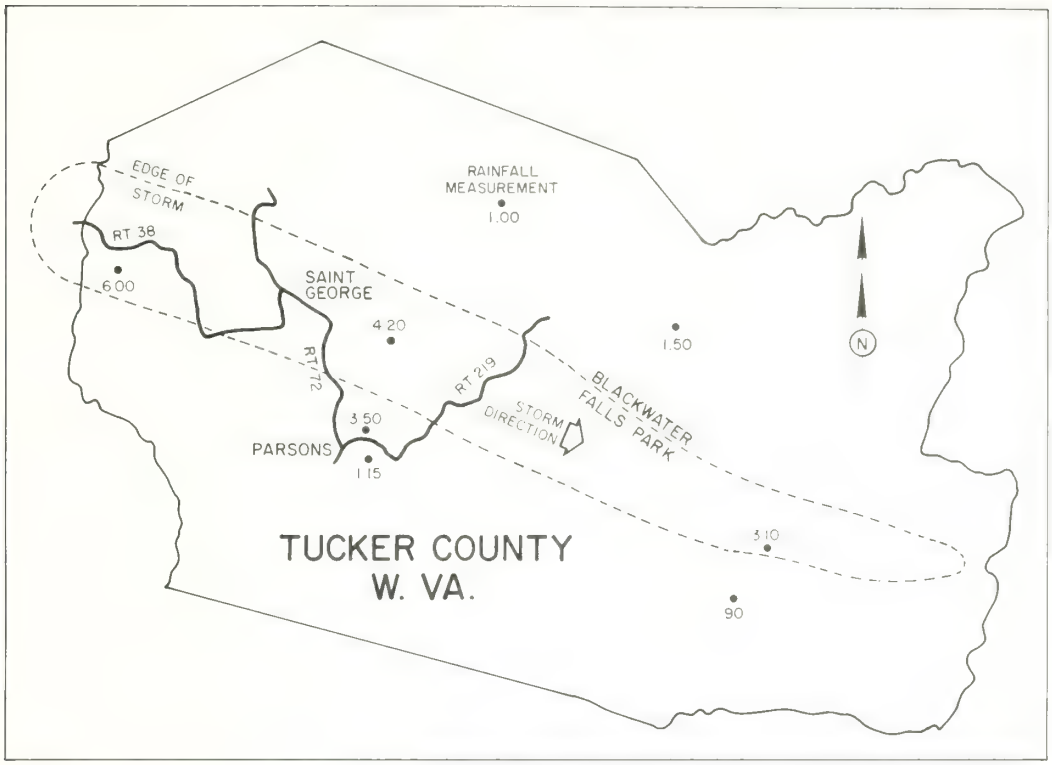

Figure 5.—The storm track.

Farther from the channels, dead leaves had been carried a few inches or even a few feet downslope, then redeposited in low cross-slope ridges behind stones or woody debris. Smaller fragments of litter often had been reoriented by overland flow with long axes downslope, giving the forest floor a "combed" appearance. This exposed the L and H layers of the soil but, apparently, overland flow had moved too slowly to tear them apart because they were bound firmly in place by roots and mycelia. Mineral soil was exposed here and there, but only in the small patches likely to be found in any steep woodland.

Most of the overland flow had originated on shallow shale soils, then drained downslope where it often reinfiltrated the deeper, more previous sandstone soils. At least 25 percent of the forest floor evidenced overland flow. Slope gradient had little relation to overland flow except that the steepest slopes often had the shallowest soil.

In general, two kinds of drainages predominated on these mountainsides. Sharply incised basins, V-shaped in cross section, evidenced most overland flow and soil erosion. Broad, gently concave basins evidenced some overland flow, but only on cross-slope belts of shallow soil, and little or no accelerated erosion was evident. So pervasive was this contrasting drainage that two typical sites were examined in detail.

A V-shaped basin

A debris deposit over a blocked culvert on Route 72 drew my attention to some severe erosion. The deposit lay beneath a vertical sandstone face about 15 feet high. I climbed the debris, only then discerning an east-facing, V-shaped basin extending upslope at a gradient close to 60 percent. Side slopes of about 70 percent extended perhaps 75 or 100 feet to sharp-crested ridges paralleling the channel. Freshet flow almost 3 feet deep had detached but left behind some sandstone slabs as large

as 4 inches thick and 24 inches across (Fig. 6). The channel was freshly eroded about a foot into the underlying bedrock. Overland flow had occurred on at least 50 percent of the side slopes.

About 300 feet up-channel, a mottled subsoil had been newly bared by erosion, but no bedrock. Here, the freshet had flowed about 2 feet deep, depositing sandstone fragments up to 2 inches thick and 8 or 10 inches across. Upslope, large plugs of soil and organic debris had lodged in the channel. Clearly, the erosive power of the freshet decreased substantially over short distances upslope. If the side slopes had eroded at all, the losses were restricted to litter carried into the channel by overland flow.

At 625 feet upslope, the channel gradient was 55 percent, with side slopes about 50 percent. The basin was no longer V-shaped, but somewhat rounded in cross section. A longitudinal band of forest floor about 2 feet wide had washed away, leaving a shallow channel of exposed mineral soil. Overland flow had occurred on perhaps 25 percent of the nearby side slopes. There, cavities in the

Figure 6.—The channel of the V-shaped basin, about 50 feet above Route 38, looking downslope. The freshly scoured bedrock is partly covered with sandstone fragments too large to be carried farther downslope. Note the scant cover of litter on channel sides. It is not possible to convey the steepness of this channel in photographs.

Figure 7.—This photographic field is about 1 square foot and shows nine piping cavities.

L and H layers (Fig. 7) suggested piping during the storm. Extending a few to several inches upslope between the organic and mineral soil horizons, were cavities 1/2 to 1 inch in diameter—probably animal burrows, which were found wherever overland flow had swept away the litter.

At 730 feet above the highway, the land still sloped 55 percent to the east but there was no clearly defined channel. Overland flow had swept away about half of the litter along a diffuse pathway about 30 feet wide, exposing mineral soil in some places.

Bedrock lay 6 to 12 inches beneath the soil surface at 850 to 980 feet above Route 72. There was no evidence of channelized flow. Here, the ground was almost planar in cross section but sloped about 70 percent to the east. Overland flow had occurred on perhaps half of the forest floor, redistributing the litter but carrying it no great distance. These evidences of overland flow were found as far upslope as 50 feet from the ridgetop.

Stereoscopic examination of large-scale aerial photographs showed that the V-shaped basin was 1,030 feet long and about 160 feet wide, almost 4 acres in extent.

A gently concave basin

From the crest of the V-shaped basin, I walked south along the ridge for 200 or more yards. Below me lay another steep east-facing basin, this one broad and gently rounded in cross section. I paced downslope, walking in its lowest discernable "channel."

There was no evidence of overland flow for the first 100 feet downslope, despite frequent outcroppings of sandstone on the 70 percent slope. Virginia creeper and poison ivy formed a dense ground cover. Along the next 100 feet downslope, shale bedrock underlaid the shallow soil; here, tiny "deltas" of soil up to 6 inches long were everywhere. Perhaps they had been caused by overland flow, but there was little evidence of litter displacement. More extensive soil disturbance

may have been prevented by the dense ground cover of jewel weed and nettles. For the next 250 feet downslope, the slope moderated to about 50 percent and was thickly covered with loose sandstone talus. Herbaceous ground and litter cover were scanty but there was no evidence of overland flow or soil disturbance. The basin narrowed gradually and its sides steepened for the next 250 feet. Loose rock covered much of the soil surface. At a point about 300 feet upslope from the highway there had been some overland flow in a shallow channel. For the last 200 feet to Route 72, stormflow had scoured away a longitudinal band of litter about 4 feet wide. The slope of this channel was about 50 percent but stormflow in it hardly could have exceeded 4 or 5 inches in depth.

Photographs taken in this basin show nothing but ordinary forest floor. There was no evidence of accelerated soil erosion. Overland flow had occurred on perhaps 25 percent of the basin surface, but most of it reinfiltrated within short distances downslope. The 18-inch culvert under Route 72 had carried the entire stormflow without plugging (Fig. 8).

Measurements on aerial photographs indicated an area of 12 acres with a length of 1,155 feet for the gently concave basin.

Recently logged land

Facing west from the ridge above the gently concave basin was a woodlot logged in 1977. Most of the trees larger than 10 inches in diameter had been cut; smaller trees remained standing. Considerable slash reinforced the soil-protective role of the forest floor, only minimally disturbed by logging during the previous year. Topography, the forest floor, and soil erosion differed little from the gently concave basin.

A truck road led downslope on 8-percent grade from a log landing about 100 yards below the ridge. There was no gullying or other evidence of severe soil loss from the

Figure 8.—Outlet of the gently concave drainage. The culvert headwall is visible at the lower center of the picture.

landing (Fig. 9) or from any logging road. Most of the finer soil particles probably had washed away during the previous winter. In any case, an existing erosion pavement of small stones and woody detritus had prevented serious soil loss during the storm of May 24.

Figure 9.—View across a log landing, downslope along a logging road with an 8-percent grade. This road had not been regraded after the storm and presented no obstacle to safe driving.

Grazed woodland

Also facing west, but from the ridge above the V-shaped basin, was a heavily grazed woodlot. Oak and maple trees of 5 to 16 inches in diameter formed a complete tree canopy but cattle had eliminated the understory. Most of the litter had been trampled into the mineral soil, creating a pocked surface irregularly covered with muddy organic matter. Here, too, topography and soil erosion differed little from that described for the gently concave basin.

Trampling since the storm may have eliminated the more subtle evidences of overland flow, but I found no evidence of accelerated erosion on nonchannel parts of the grazed woodlot. Apparently rain had infiltrated as fast as it fell. Where drainageways narrowed and deepened to define a channel, there was the same evidence of severe channel scour described for the V-shaped basin. There was no evidence that scour had been worsened by grazing. As in the V-shaped basin, erosion of soil and rock increased greatly over short reaches of deeply incised channel.

Landsliding

Slope failures above roads and streams were common, but only one landslide (Fig. 10) was found on the storm track. It was on a 58-percent slope between Routes 38 and 72. Almost 100 feet wide and perhaps twice as long, it dumped nearly 1,500 cubic yards of debris into Clover Run. Monongahela National Forest personnel believe that road

Figure 10.—Landslide on the Right Fork of Clover Run. The lightest colored surfaces are bedrock. For scale, note workmen at the top of the photograph.

construction caused this landslide. Loss of slope support from bank undercutting by Clover Run seems as likely a cause. Upstream a short distance, another landslide of similar size had occurred long before the forest was roaded.

An estimate of debris production

Heavy rain caused stream channels to extend far upslope, often into land showing no previous overland flow (Fig. 11). Here, the erosive action probably was like that described for the V-shaped basin. Scour was severe, too, in small headwater hollows (Fig. 12), the origin of mere trickles during ordinary wet weather. Bank undercutting was ubiquitous, with several slope failures per mile common along perennially flowing, first-order headwater streams (Fig. 13). Huge stormflows had widened and deepened the second- and third-order stream channels (Fig. 14). Debris from all of these upstream

Figure 11.—Overland flow on shallow Dekalb soil cut this channel on a 40 percent slope where no channel had existed.

Figure 12.—This ephemeral channel near Route 38 was scoured to bedrock and greatly widened.

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1981. **Soil-water relations of shallow forested soils during flash floods in West Virginia.**
Northeast. For. Exp. Stn., Broomall, Pa.
20 p., illus. (USDA For. Serv. Res. Pap. NE-469)

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Figure 13.—Water had flowed at least 4 feet deep far up the headwaters of Clover Run. Several slipouts of this size or larger occurred per mile along its streambanks.

Figure 14.—Stormflow in Mill Run rose to the guardrail on this bridge. The large sycamore tree to the right of the bridge was undermined by bank undercutting. Note the size of rocks carried downstream by the flood waters.

sources was deposited downstream where channels widened and flattened (Fig. 15), or where tributaries joined larger streams (Fig. 16).

Debris at the mouths of Wolf Run (Fig. 15), Jonathan Run (Fig. 16), and an unnamed hollow near St. George (Fig. 2) had been deposited in discrete, easily measured piles. Tonnage of these piles was estimated by multiplying their volume in cubic yards by 1.4, a factor recommended as realistic by a local stone and gravel company.

Based on its modal profile description (Losche and Beverage 1967), Dekalb soil is about one-third rock fragments. I assumed that two-thirds of the nonrock particles eroded from the channels of Wolf and Jonathan Runs had been flushed into the Cheat River. A higher proportion of soil and organic matter remained in the deposit below the unnamed hollow; here I assumed that only half of the nonrock particles had been flushed into Clover Run. These assumptions provided a basis for estimating debris production from these drainages (Table 1).

Table 1.—Estimates of debris production from forested watersheds during the storm of May 24, 1978

Watershed	Area[a]	Eroded Material	Debris per acre of	
			Watershed	Channel
	acres		*tons*	
Wolf Run	1,000	2,766	2.8	56
Jonathan Run	980	2,987	3.1	62
Unnamed hollow	33	318	9.6	192

[a]Planimetered from U.S. Geological Survey quadrangle maps.

Although overland flow had been common around St. George, only organic matter was carried across the forest floor in appreciable amounts. Even the logging roads showed only slight soil losses. Freshet flows had scoured

Figure 15.—Huge amounts of gravel were deposited near Wolf Run's confluence with the Cheat River. Note road pavement swept away.

Figure 16.—Debris from Jonathan Run at its confluence with the Cheat River. The largest object found in this deposit, a concrete block of about 2 cubic feet, indicated the carrying power of the flash-flood waters.

far more rock, soil, and organic matter from the channels of perennial and ephemeral streams.

Expressing debris production as loss per acre of watershed is customary but misleading because acres never erode equally. It seems more realistic to express debris as amount per acre of stream channel. Assuming that 5 percent of each watershed had been subject to freshet flow at the height of the storm, debris production also was expressed as loss per acre of freshet channel (Table 1)

SOIL-WATER RELATIONS ON THE LEETONIA-BRINKERTON SOIL ASSOCIATION

These soil-water relations were observed east of Route 219, near Blackwater Falls State Park. Here, a nearly flat plateau of sandy soil overlies coarse-textured sandstone and conglomerate (Losche and Beverage 1967). Elevation is about 3,500 feet. Young northern hardwoods are mixed with hemlock and red spruce, with few trees exceeding 12 inches in diameter. This area had regrown slowly since it was logged and burned about 60 years ago. Mountain-Laurel, rhododendron, and blueberry form an understory of variable density. Litter was 2 to 3 inches deep.

Evidences of overland flow were less common here than on Dekalb soils, possibly because of sandier soil, flatter slopes, thicker litter, and somewhat less rainfall. Most commonly found were bands or low ridges of litter, mostly spruce and hemlock needles, that marked high water levels parallel to ephemeral as well as perennial channels. The bands were an inch or two wide, about half as high, and a few feet to many feet long. Perhaps 20 or 25 percent of the land surface had been subject to some sort of gentle inundation, seldom having greater erosional effect than the formation of litter bands along the periphery of inundated areas.

Given the flatter topography of this plateau, there was no high-velocity overland flow and associated erosion on the forest floor. Only the stream channels eroded severely, often as severely as channels in the St. George vicinity. Here too, erosion damage to logging roads was minimal (Fig. 17 and 18). Most of these roads had been little used

Figure 17.—Erosion pavement on a logging road with an 8-percent grade near Canyon Rim Road, Blackwater Falls Park. This was the most severely eroded road found and most of the soil loss probably occurred before the storm of May 24.

Figure 18.—Erosion on a logging road with a 15 percent grade near Tub Run. Note accumulation of eroded material at slope change, a common deposition site.

for years; probably an erosion pavement had formed on them long before the storm of May 24. Grazing, too, had little effect on soil-water relations.

TWO SUMMER STORMS ON THE WEIKERT-BERKS SOIL ASSOCIATION

The summer of 1978 was rainier than usual over much of West Virginia (U.S. NOAA 1978). Moreover, several flash floods were reported during the first 2 weeks of August, but they occurred too far from Parsons for detailed poststorm observation. I was fortunate, however, to visit all of the sites once and the Weikert-Berks sites twice, the second time accompanied by John Gorman, West Virginia's Woodland Conservationist for the U.S. Soil Conservation Service.

Baker Run, Hardy County, storm of August 3

An account of this storm is in the August 6 issue of the Moorefield Examiner. An unusually good unofficial record of rainfall was obtained by four amateur observers in the Needmore area, at the headwaters of Baker Run. One of them, Mr. Gordon Combs, collected 4.1 inches of rain between 7:30 and 8:15 p.m., with hard rain stopping at 9 p.m. At least 5 inches of rain fell within 2 hours, at a maximum intensity exceeding 4 inches per hour. Three miles downstream from the Combs residence, Baker Run flowed 15 feet deep and 295 feet across at the height of the storm. This was the only flash flood causing loss of human life.

Our most detailed observations were on the Ewing farm, adjacent to the Combs property. Soils of the Weikert-Berks series (Curry 1978) are 20 to 40 inches deep over shale bedrock. Both woodland and pasture were heavily grazed by cattle and sheep, but neither showed accelerated soil erosion. There was no evidence of erosion on a woodlot clearcut in 1971, even on a logging road with a 25-percent grade. Localized overland flow may have occurred in grazed woodland, where slopes seldom exceeded 40 percent, but there was no accelerated erosion. Leaves, mud, and stones up to 2 inches in diameter formed scattered alluvial deposits in a headwater stream draining the Ewing farm. Channel scour was not nearly as severe in any headwater stream as in Baker Run itself.

About 1 acre of grazed woodland had been remarkably scoured by overland flow (Fig. 19). There, slopes of 35 to 40 percent had been heavily grazed, leaving a complete tree canopy but no understory. If overland flow occurred frequently on grazed land, these downslope belts, swept clear of litter, would be commonplace. They are unique to my long experience in forest hydrology.

North of the Ewing residence, a debris avalanche (Fig. 20) had occurred on a 55-percent slope in grazed woodland. The avalanche scar was about 20 feet wide, 50 feet long, and 2 feet deep to bedrock. The debris slid about 700 feet to the base of a 40- to 45-percent slope. It must have flowed as a semiliquid mass because grass and small trees were bent over but not uprooted by its passage. Five smaller (200 to 300 square feet) landslips were found close to the base of a 40-percent grassy slope nearby.

Johnson's Run, Grant County, storm of August 5

An account of this storm is carried in the August 9 issue of the Grant County Press. East of Johnson's Run, Mr. Raymond Armentrout (NOAA observer) measured 2.80 inches of rain falling between 3:30 and 4:30 p.m. Mr. J. A. Graham, a farmer west of Johnson's Run, measured 3.6 inches in a glass gage. The superintendent of the Petersburg trout hatchery confirmed the storm timing but had no rainfall measurement.

Johnson's Run gives a first impression of severe channel scour (Fig. 21). Debris strewn about the channel area is nearly all sandstone but this watershed is underlain with calcareous shale. Most of the debris came from Buchanan soil, a sandstone-derived series to the east that overlies the shale. The road east of Johnson's Run cuts into this sandstone and had been rebuilt several times, most recently since the storm of August 5 (Fig. 22). Several large gullies on 30 to 40 percent slopes have

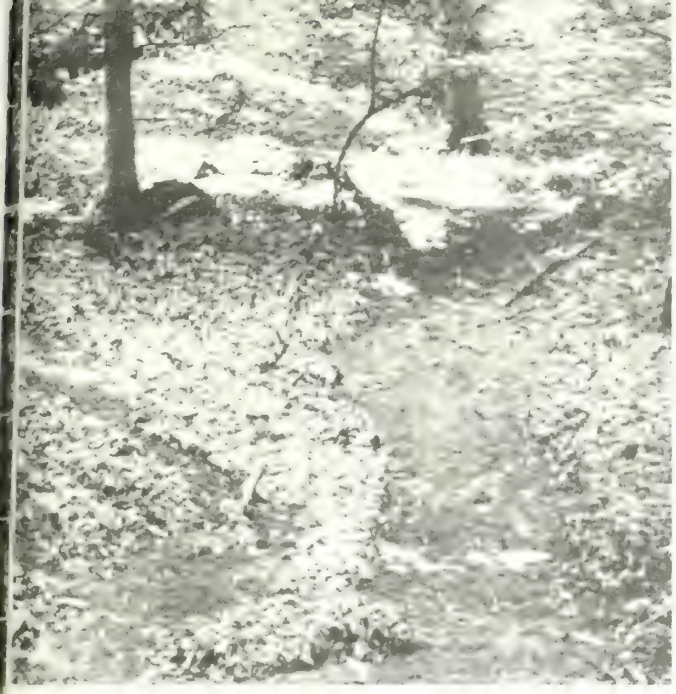

Figure 19.—Overland flow paths on grazed woodland. The largest path is 3 to 4 feet wide, litter ridges on each side about 1 foot high. The H layer was not disrupted and mineral soil was not exposed.

Figure 20.—About 70 cubic yards of soil and rock were dislodged from this debris avalanche scar.

Figure 21.—The main channel of Johnson's Run, downstream from the outlets of gullies caused by road drainage.

Figure 22.—These road banks are 8 feet high, the ditches 2 feet deep, the traveled road surface 24 feet wide. The roadbed is on sandstone bedrock at a grade of 9 percent. The road was completely washed out by the flash flood.

carried road debris into Johnson's Run for years (Fig. 23). Surely, this road and its associated gullies are the sources of sandstone debris strewn about the stream channel. The streambed of Johnson's Run had scoured to its shale bedrock but there had been only minor loss of soil and organic matter from its tributary channels.

Cattle have grazed for years on the forested Weikert-Berks soil of this watershed. In 1972, a 50- to 60-percent slope was clearcut and it too, has been grazed since. There were no signs of accelerated erosion on the clearcut or on skid roads ascending its steepest slopes. Nor was there accelerated erosion on steep (up to 70 percent) pastured woodland adjacent to the channel of Johnson's Run. Overland flow had occurred on not more than 5 percent of the forest floor.

Figure 23.—Tons of debris from the road shown in Figure 22 poured down this 35-percent pastured slope. Johnson Run is about 200 yards downslope from the fence.

OTHER FLASH-FLOOD SITES VISITED

At least six other flash floods were reported in West Virginia during those first 2 weeks of August. I visited five of the sites (Table 2). Some notes on conversations with residents, a few photographs, and some hasty field observations constitute my meager record. Nevertheless, findings there conform closely to those reported for the Weikert-Berks complex.

1. There was no evidence that rainfall intensities ever exceeded infiltration capacity of the forest floor. In other words, overland flow played an insignificant role in whatever soil erosion occurred.
2. Harvest of wood products and grazing had no visible effect on soil erosion.
3. Flash floods did not materially accelerate soil erosion on logging roads.
4. Scouring in headwater (first order) channels removed little more than organic matter and some soil.
5. For a given flash-flooded watershed, scouring and overflow were severe only in the channels of larger (second- and third-order) streams.

Flash-flooding had similar effects in May and August with respect to infiltration, woodland grazing, and logging roads. Channel overflow and scour in large, perennial streams were similar, too (Fig. 24). Only in the tiny, ephemerally flowing, first-order channels was there contrasting behavior. Most of these had carried damaging freshet flows in May and were deeply eroded; in August, flows and erosion were negligible in all of them (Fig. 25).

Table 2.—Location and characteristics of August 1978 flash floods in West Virginia

Storm site	County	Date	Storm characteristics		
			Rainfall	Duration	Intensity
			inches	*hours*	*in/hr*
Watershed of Dumplin' Run	Grant	8/6	5.00	2.5	2.0
Village of Mathias	Hardy	8/6	3.78	6.5	0.6
Watershed of Hizer Creek	Putnam	8/10	3.50	2.0	1.8
Town of Moorefield	Hardy	8/11	2.65	2.0	1.3
Watershed of Sugar Creek	Kanawha	8/11	3.50	1.0	3.5

Figure 24.—This 4-foot culvert had provided access to a small farm on the right. Dumplin' Run washed away the newly repaired gravel road on the left.

Figure 25.—This tributary of Dumplin' Run has a channel gradient of 25 percent. Litter was flushed out but there had been no heavier scour. There was no evidence of overland flow on the 70-percent channel banks.

ARE THESE SOIL-WATER RELATIONS TYPICAL?

The storms that caused these flash floods are atypical. Rainfall intensity data for the Middle Atlantic Region (U.S. Department of Commerce 1958) show that storms ranging from 2.3 to 3.4 inches in 1 hour, and storms ranging from 3.8 to 5.4 inches in 6 hours, are likely to occur only once per century in this part of West Virginia. All of the flash-flood sites were subject to storms of these or greater intensities. Even at these phenomenal intensities, most of the rain infiltrated as fast as it fell. Surely, no less infiltration can be expected during lesser storms. To this extent, soil-water relations were typical.

Dekalb-Calvin, Leetonia-Brinkerton, and Weikert-Berks soil complexes are widespread in northeastern West Virginia, and they are taxonomically similar in many respects. All range from 20 to 40 inches to bedrock. Coarse fragment content is high in subsoil; from 15 to 75 percent in B horizons, from 60 to 90 percent in C horizons. This stoniness causes high soil densities, ranging from 1.5 to 1.9. Dekalb has about 50 percent greater waterholding capacity than other soils, the only difference of obvious hydrologic significance in their profile descriptions.

Had rains been even heavier, I suspect that channels in the V-notch basins would have eroded even more severely. The erosion mechanisms (overland flow and channel scour) would be unchanged from the storm of May 24, but greater volumes of overland and channel flow would greatly increase losses of soil and rock. Short ridge-to-channel distances provide highly efficient drainage across and within soils on such rough topography.

Forest soil-water relations during flash flooding probably differ little on any of these soils when the surface configurations of the soil and bedrock are similar. But similar configurations are rarely found, even on a given slope. They came closest to being similar on the gently concave basin. There, with minor exceptions, erosion was minimal because water was contained in and drained rapidly through a relatively deep soil on a relatively uniform slope. Far more complex soil-water relations prevailed in the V-shaped basin. There, in effect, the deeply incised channel greatly shortened slope lengths. Poststorm evidence suggested exfiltration all along its channel margins. Rain falling on exfiltrated water was transformed instantly to overland flow; in effect, causing channel interception on an enormously lengthened and widened channel. So much water flowing so rapidly eroded the V-notch severely. Water yield per acre probably was identical from the V-shaped and gently concave basins but, from the erosion standpoint, the timing of the flows was more critical than their total amount.

More rain falling on the gently concave basin would have thickened the strata of saturated soil, forcing water to exfiltrate farther upslope. The resulting overland flow might have eroded the soil, but landsliding would have been a more serious threat. Thickened strata of saturation would have increased soil-pore water pressure, increased soil buoyancy, and decreased soil shear strength (Swanston 1969). These are effects of complete infiltration during heavy rain that unavoidably lead to debris avalanching, a condition only verged upon in the 1978 flash floods. Landsliding was severe during a 12-inch storm at Petersburg, West Virginia (Allard 1951) and disastrous in a 28-inch storm in nearby Nelson County, Virginia (Woodruff 1971). Thus, nearly unlimited infiltration coupled with efficient internal drainage minimizes erosion by overland flow but poses the greater erosion threat of debris avalanching on smooth topography.

Erosion thus related to topography has been observed on shallow forest soils in southeast Alaska (Bishop and Stevens 1964). There too, the channels of V-shaped basins were severely eroded but relatively smooth slopes were more prone to debris avalanching.

Given similar capability of all soils to infiltrate and drain phenomenal rains, why were overland flow and soil erosion so much greater in May? At that season, Dekalb and Leetonia soils probably were near capacity in water content. There are only clues as to how much less water the other forest soils may have contained in August. Our best clues are from the Fernow Experimental Forest,

near Parsons, where abundant data are available concerning the soil-water relations of Calvin silt loam. It is wettest in springtime, containing as much as 15 inches of water in the upper 4 feet of soil. Transpiration by trees is most rapid in June and July, lowering midsummer moisture content to about 10 inches of water (Patric 1973). Thus, Calvin soil has retention capacity for about 5 more inches of rain in midsummer than in early spring. Presumably, the Weikert-Berks series, too, had greater rain-retention capability in August. The drier the soil at the onset of a storm, the more rain is needed to start the sequence of saturation, exfiltration, overland flow, and soil erosion.

These results are important because the soils, vegetation, topography, and land use on the flash flooded sites typify much forested land not only in West Virginia but in most of the central Appalachian region. But atypical indeed are the rates of debris production caused by these storms. Their atypicality is important in itself, partly because it implies rare occurrence, but mostly because it defines a ceiling—an amount highly unlikely to be exceeded during ordinary weather. A floor, 0.05 to 0.10 ton per acre per year (Patric 1976), is generally accepted as the usual erosion rate of forest land in the Eastern United States. Hewlett (1979), too, estimates about 0.05 ton of soil loss per acre per year between cutting cycles on the more erodible soils of the Georgia piedmont, about 1 to 2 tons during and immediately after clearcutting and pine planting. Hewlett's data, falling well within the preceding floor and ceiling values, suggest that these lower and upper limits of soil loss may hold for forest land even beyond the Appalachian region.

The U.S. Soil Conservation Service (1979) estimates a national soil-loss rate averaging 4.8 tons per acre per year from cropland, and 10.6 tons for the Appalachian states. Whether my estimates of debris production and their estimates of soil loss are comparable is unclear. It is clear, however, for the central Appalachian region, that only rare phenomenal rates of debris production from forest land even approach the average rates of soil loss said to occur annually on cropland. These contrasting rates alone provide a useful perspective for evaluating the relative significance of erosion from farm and forest as a conservation problem.

The limited infiltration cited by Wadleigh (1966) unquestionably determines runoff and soil erosion from such relatively impervious land surfaces as highways, cities, and fields. People familiar with such land surfaces but unfamiliar with forest soil-water relations erroneously attribute overland flow and soil erosion in forests to limited infiltration capability.

From these observations, I conclude that the soil-water relations described here are implicit in the original description of the variable source area. (Southeastern Forest Experiment Station 1961). More fully described and modeled by Hewlett and Troendle (1975), the concept embodies current understanding of soil-water relations on forest land. The key is complete infiltration. Under prolonged rainfall, zones of exfiltration expand upslope, in effect lengthening and widening stream channels. When rain stops, exfiltration diminishes and channels shrink to prestorm dimensions. Overland flow and piping contribute to the drainage process, but only as the soil saturation that is prerequisite to their functioning develops. Differences in stormflow and erosion occurred not because the behavior of water in the soils differed, but because infiltrated water performed the same way in forest-soil-bedrock complexes of differing configuration and antecedent wetness.

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by Keith F. Jenson

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Abstract

One-year-old seedlings of yellow-poplar (*Liriodendron tulipifera* L.), eastern cottonwood (*Populus deltoides* Bartr.), and white ash (*Fraxinus americana* L.) were divided into four groups. One group served as the control, and the other groups were fumigated for 12 hours per day with either 0.1 ppm O_3, 0.2 ppm SO_2, or 0.1 ppm O_3 plus 0.2 ppm SO_2. Two or three seedlings of each species were harvested twice a week for 6 weeks, and leaf area and new growth weight were determined. Data on leaf area and new growth weight were transformed to natural logarithms and fitted with a linear regression model. Relative growth rate was positive in all species-treatment combinations, but varied with fumigation treatment. Net assimilation rate was suppressed in cottonwood seedlings in all fumigation treatments, and in yellow-poplar seedlings in the SO_2 and O_3 fumigations. Relative leaf area growth rate of the cottonwood and yellow-poplar seedlings was reduced by all three fumigation treatments. White ash growth was not analyzed because statistically significant differences were not found.

DO AMBIENT CONCENTRATIONS of atmospheric contaminants affect the growth and development of plants? The answer to this critical question is needed to establish environment standards for air pollutant concentrations and to calculate economic gains or losses.

The question has been addressed (Ashenden 1978, Bleasdale 1973, Heagle et al. 1973, Heck 1973, Jensen and Masters 1975, Mandl et al. 1973), but as the concentration of pollutants being investigated is reduced nearer and nearer to ambient levels, the problem of detecting effects rapidly increases. To determine statistically valid effects of low pollutant doses, large numbers of plants and long periods of fumigation are required. This greatly increases the cost and complexity of the research.

One method that may help in avoiding these problems is classical growth analysis (Oshima et al. 1978). Growth analysis divides growth into component processes, and focuses attention on rates of growth instead of on final yield or growth. It utilizes dry weight and leaf area measurements collected from periodic harvests, and partitions growth among component characteristics. The parameters from growth analysis can be used to compare the effect of various treatments on plant growth (Ledig 1974).

In this study growth analysis techniques were used to analyze and compare growth parameters of hardwood seedlings fumigated at low pollutant concentrations.

MATERIALS AND METHODS

One-year-old seedlings of yellow-poplar (*Liriodendron tulipifera* L.), eastern cottonwood (*Populus deltoides* Bartr.), and white ash (*Fraxinus americana* L.) were weighed and potted in a 1:1 sand-soil mix in 15 cm pots. After 144 seedlings of a species had broken bud, they were randomly divided into four groups and assigned to fumigation treatments. The plants were watered as needed and fertilized with soluble fertilizer (20-20-20) every second week.

The treatments were control, 0.1 ppm O_3, 0.2 ppm SO_2, and 0.1 ppm O_3 plus 0.2 ppm SO_2. The treatments were applied 12 hours a day, 7 days a week, in four circular chambers similar to those described by Heck and others (1978). The chambers were 1.5 m in diameter and height. They were covered with Teflon[1] film, and had flow-through air systems. The pollutants were added to the charcoal-filtered air stream before it entered the chamber, and automatically sampled in each chamber every 20 minutes. The SO_2 concentration was measured with a Beckman 906A SO_2 monitor, and the O_3 concentration was measured with a Beckman 950 ozone monitor. The

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an offical endorsement or approval by the U.S. Department of Agriculture or the Forest Service of any product or service to the exclusion of others that may be suitable.

average temperature in the chambers was 29°C, and the relative humidity ranged between 35 and 75 percent. Because the chambers were small, only two species could be treated at one time. Yellow-poplar and white ash were treated in the first study, and eastern cottonwood was treated in the second study.

One week after the fumigation was initiated, three randomly preselected seedlings were harvested from each treatment on Monday and Thursday of each week. The height of each seedling was measured to the nearest mm, and leaf area was measured to the nearest square centimeter with an automatic area meter. The leaves were then combined with the new shoot (stem growth for the current season) and dried to constant weight at 100°C. Plants were harvested for 6 weeks. Near the end of the study some seedlings had died, and then only two seedlings were harvested from some treatments.

Data on the height, leaf area, and new growth dry weight were transformed to natural logarithms and fitted with a l regression model as a function of (Hughes and Freeman 1967). Growth an parameters were calculated from the mo growth curves (Radford 1967).

RESULTS AND DISCUSSIO

To test if the treatments affected growth parameters I did an analysis of c iance. I found statistically significantly ferences between treatments for the follo variables: cottonwood height, leaf area, growth dry weight, and yellow-poplar area and new growth dry weight (Figs. 1 2). Relative growth rate (RGR), leaf ratio (LAR), relative leaf area growth (RLAR), and net assimilation rate (N were calculated for cottonwood and yel poplar (Table 1). White ash growth was analyzed further because statistically sig cant differences were not found.

Figure 1.—Response of cottonwood seedlings to fumigation.

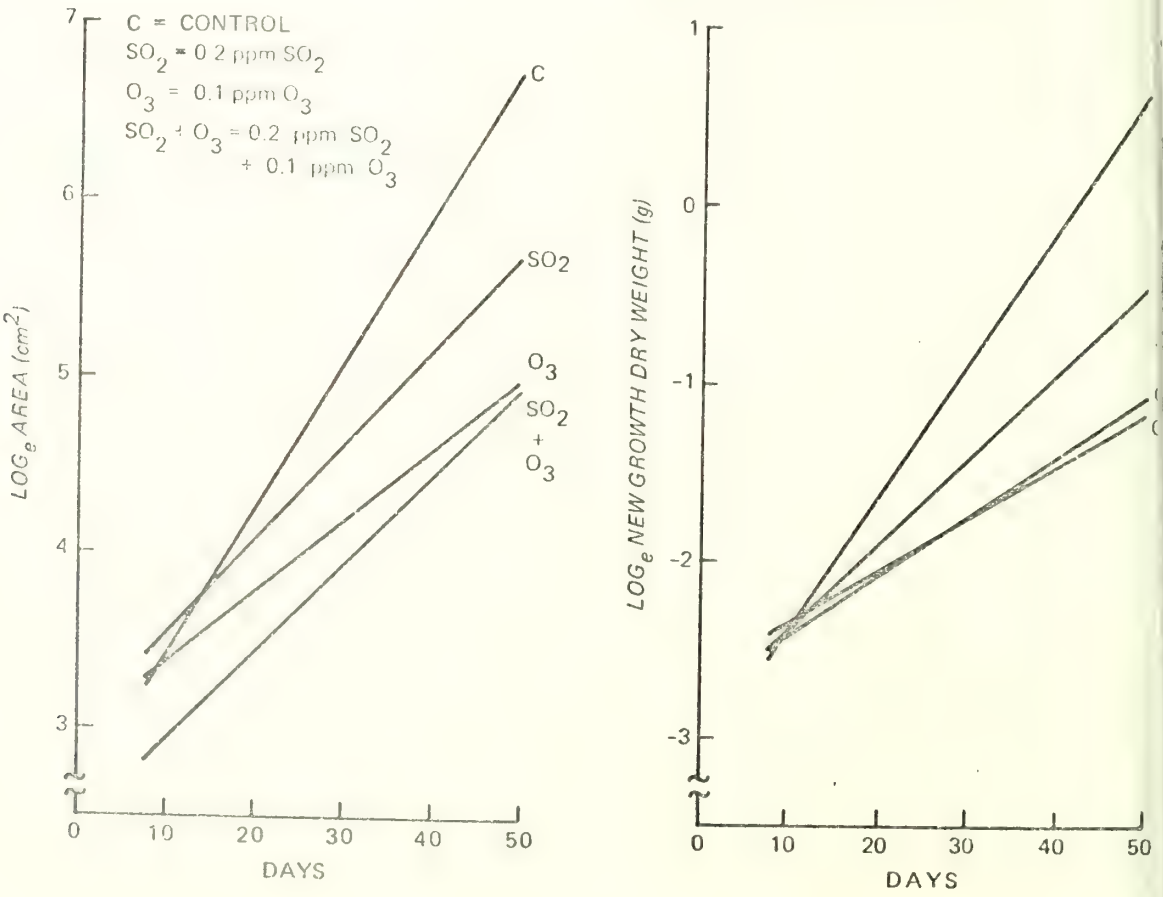

Figure 2.—Response of yellow-poplar seedlings to fumigation.

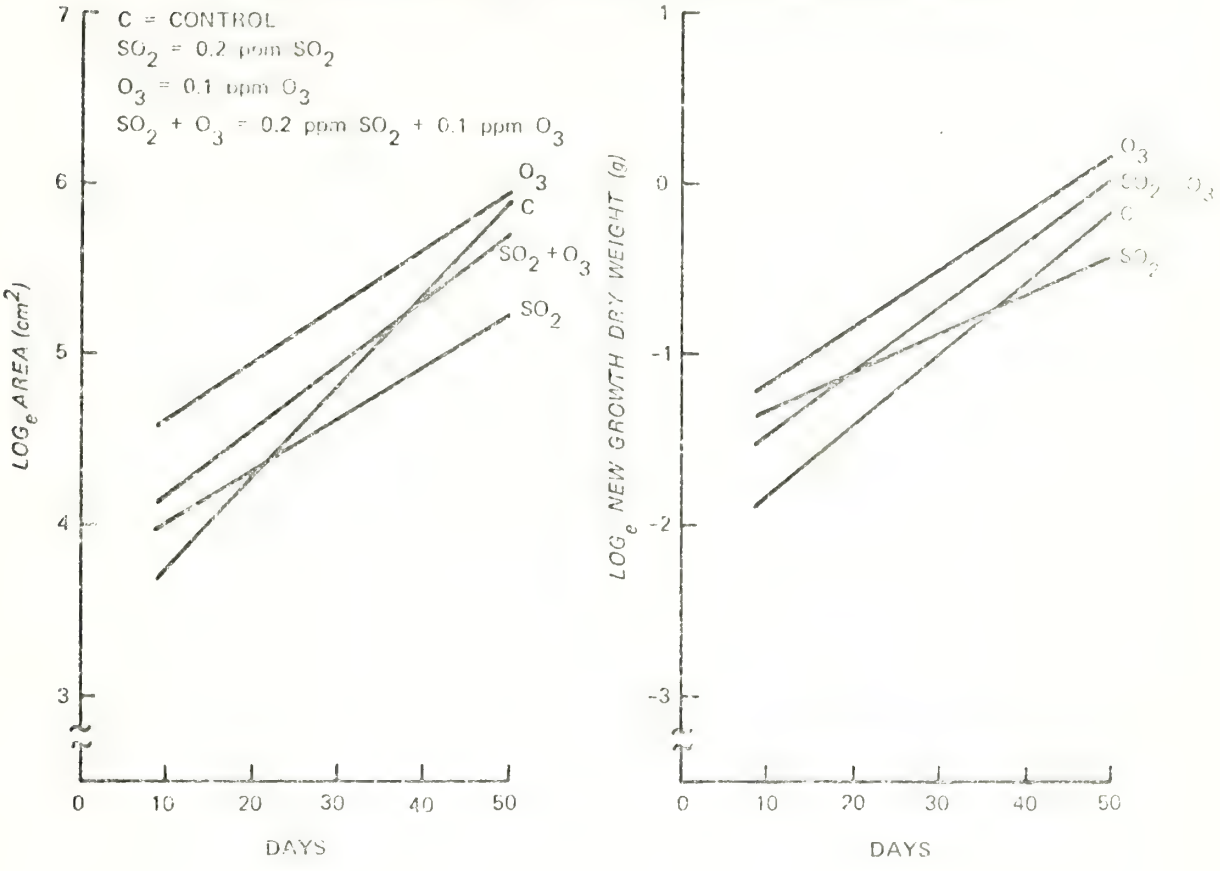

Table 1.—Growth parameters of hardwood species fumigated with air pollutants.

Species treatment	Relative growth rate	Leaf area ratio	Net assimilation rate	Relative leaf area growth rate
	g/(g· day)	*cm^2/g*	*g/(cm^2· day)*	*cm^2/(cm^2· day)*
Cottonwood:				
Control	0.0750	393	0.190	0.0838
SO_2	0.0482	424	0.113	0.0526
O_3	0.0304	377	0.080	0.0400
O_3 + SO_2	0.0335	296	0.113	0.0528
Yellow-poplar:				
Control	0.0419	342	0.122	0.0518
SO_2	0.0198	257	0.077	0.0307
O_3	0.0338	331	0.102	0.0328
O_3 + SO_2	0.0391	276	0.136	0.0400

Relative growth rate (RGR) is a measure of productivity, and expresses the growth rate relative to the amount of growing material present (Ledig 1974). RGR is equal to the slope of the linear regression model calculated for dry weight. RGR was positive in all treatment combinations, but varied with fumigation treatment. Compared to the control seedlings the RGR of the cottonwood seedlings fumigated with SO_2 was reduced by more than 30%, and the RGR of the yellow-poplar seedlings was reduced by more than 50%. The RGR of the cottonwood seedlings fumigated with O_3 was only 40% of that of the control seedlings, while the RGR of the yellow-poplar seedlings fumigated with ozone was only reduced by 20%. The RGR of the yellow-poplar seedlings fumigated with both gases was only slightly less than that of the controls, while the RGR of the cottonwood seedlings in the same treatment was reduced more than 50%.

RGR is a complex function and has been viewed as an efficiency index. In this study RGR was based only on the weight of the new stem and leaves produced during the study, and did not include the original stem and root weight. This approach was selected because the original stem and roots contribute little to the overall production process (Watson 1952).

The reduction in RGR after fumigation suggests that the dry weight needed to produce an additional unit of dry weight was increased by fumigation. This could be caused by a decrease in the photosynthetic rate, an increase in the respiration, or a change in the partitioning of photosynthate between the stem and the leaves. RGR can be examined further by dividing it into two additional growth parameters, leaf area ratio (LAR) and net assimilation rate (NAR); RGR is equal to NAR times LAR.

LAR (leaf area/plant dry weight) was calculated for the 30th day of the study and divided into RGR to calculate NAR for the same day. LAR is an index of leafiness and expresses the relationship of assimilatory surface to respiratory mass (Ledig 1974), and NAR is an index of physiological activity and a measure of the change in dry weight per unit area per unit time.

LAR of the cottonwood seedlings fumigated with $O_3 + SO_2$ and the yellow-poplar seedlings fumigated with SO_2 and $O_3 + SO_2$ was reduced markedly (Table 1). NAR was suppressed in all fumigated cottonwood seedlings and in yellow-poplar seedlings fumigated with SO_2 and O_3 alone (Table 1).

LAR declines with a decrease in leaf area or an increase in the respiration rate per unit leaf area (Watson 1952). The reduction in leaf area might be caused by early leaf senescence or early bud set. Air pollution causes early leaf senescence in hardwood and citrus trees (Jensen and Masters 1975, Thompson and Taylor 1969).

NAR is a measure of the photosynthate changed into plant structures or stored in the plant after respiration demands are met. It is a function not only of the rate of photosynthesis but also the respiration rate. It measures how efficiently photosynthate is used or stored in the plant. NAR might be reduced by pollutants inhibiting photosynthesis (Ormrod 1978) or causing an increase in the respiration rate (Mudd and Kozlowski 1975).

The final parameter that was calculated was RLAR, relative leaf area growth rate. It is equal to the slope of linear regression model calculated for leaf area. RLAR decreased in all fumigated cottonwood and yellow-poplar seedlings.

A decrease in RLAR means that a larger area is required to produce an additional unit of leaf area. Thus, it supports the conclusion suggested by RGR that the overall efficiency of the growth process declines after fumigation.

Growth analysis suggests that ozone and sulfur dioxide reduce the growth of some hardwood seedlings by reducing their growth efficiency. The analysis does not pinpoint the process or processes that are influenced, but it does suggest that growth is retarded. This is supported by RGR and RLAR that require more weight or area to produce each additional unit. It is also supported by NAR that decreased with fumigation in all but one case. The differences that were calculated might appear to be extremely small and thus unimportant. However, a reduction of only 0.01 g/(g· day) on a 100 gm plant would result in a reduction in dry weight of more than

8 gm in one week. A change of RGR of this magnitude, or even less, would probably have a significant effect on trees over an entire season or over several years.

Watson (1952) and Shibles and MacDonald (1962) stated that leaf area or leaf area growth rate was better correlated with the total plant growth rate than photosynthesis. To evaluate these relationships in this study, the coefficients of correlation between RGR and NAR and RLAR were calculated. The coefficient between RGR and NAR was 0.90 and between RGR and RLAR was 0.83. Both correlations were fairly good but were based on only a small sample, so no definite conclusion could be reached in this study.

In general, O_3 reduced growth in cottonwood more than SO_2, while SO_2 reduced growth in yellow-poplar more than O_3. When both gases were used, growth was not reduced as much as in the single gas fumigation. This suggests an antagonistic relationship between the two gases.

In this study only the initial, log-linear, portion of the growth curve was analyzed. More useful information could be obtained from regression models describing growth over entire seasons. The change in growth parameters over a longer period of time would allow a more thorough examination of the growth relations.

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